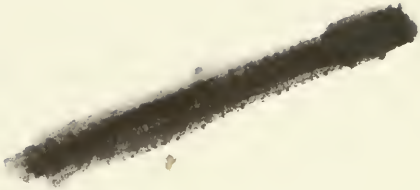

TRANSACTIONS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS.

(INSTITUTED 1852.)

VOL. VII.
JANUARY TO DECEMBER, 1878.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.

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CLIII.

(Vol. VII. January, 1878.)

ON IGNITING BLASTS BY MEANS OF ELECTRICITY.

By JULIUS H. STRIEDINGER, C. E., Member of the Society.

For which the Norman Book Prize was awarded, November 7th, 1877.

I.

The great blast recently attempted at Port Henry Iron Mine was only a partial success. Its failure has been attributed to either imperfect electrical arrangements or to the freezing of the nitro-glycerine compounds used, or both.

On the other hand we learn, that two serious accidents have happened within a few months at the mouth of the Sutro Tunnel, both through the sudden and apparently unaccountable discharge of a number of exploders. An investigation into the cause of these accidents clearly established the fact, that in the exceedingly dry atmosphere of the high plateau between the Sierra Nevada and the Rocky Mountains, certain frictional fuses can be set off by electricity accumulated in the human body.

Such discouraging occurrences naturally lead us to inquire whether, in our present state of knowledge of high explosives and their mode of

detonation no reliable means exist of preventing a repetition of similar misfires and premature explosions. In considering these points the following questions suggest themselves :

1. *Is it possible to fire, with certainty, simultaneously a large number of mines?*

2. *Can frozen nitro-glycerine compounds be detonated?*

3. *Can the use of over-sensitive fuses be avoided?*

That a large number of mines can be simultaneously successfully fired was demonstrated by General Newton's blast of Hallet's Point Reef, where over 3,600 separate charges were simultaneously exploded. The method here adopted consisted in dividing all the mines to be ignited by electricity into a large number of independent groups, supplying sufficient battery power for each group to fire with certainty all the fuses in the group, and then at the requisite moment simultaneously closing the circuits of all the groups by means of the gravity circuit closer of J. H. Striedinger and A. Doerflinger, illustrated by the annexed drawings. *Plates I, II and III.*

As the number of cups and pins can be increased at will, and since the probability of firing a number of mines increases with the number of groups into which they are divided, and the probability of detonating a single charge is proportional to the number of independent fuses placed into it, it follows, that the writer's *method of simultaneously firing an unlimited number of independent groups offers a sure means of preventing misfire,* and that five thousand charges can with the same degree of certainty be ignited as ten.

In reference to the second point, it is only necessary to state, that numerous experiments have proved, that *nitro-glycerine compounds can as surely be detonated when frozen as when not congealed,* provided a fuse, containing not less than twenty grains of good fulminate of mercury * or its equivalent, is used.

Before answering the 3rd question :

"*Can the use of over-sensitive fuses be avoided without giving up blasting by means of electricity,*" we should state, that the frictional blasting machine and frictional electric fuse were successfully used by the Sutro Tunnel Company for a number of years without any accident whatever, until last December, since which time the two serious ones, already mentioned, have occurred.

---

* Compare Annual Report of the Chief of Engineers U.S.A., 1875. Part 2. Page 209.

The explanation which can be given is, that competing manufacturers have been in the habit of increasing more and more the sensitiveness of their exploders in order to earn for them the reputation of certainty of detonation in great numbers.

The use of over-sensitive exploders may be avoided :

1st. *By the exclusive employment of a safe priming—(as for instance, Brown's composition No. 4)—in the construction of electric fuses.*

2d. *By the examination of fuses before they are given to the blaster.*

By exposing each fuse to electric discharges somewhat exceeding those derived from the accumulated electricity in the human body the safety of the exploder is readily proven. A Holtz machine without Leyden jars, or the induction coil connected with a few constant cells are suitable apparatuses for such tests.

The objections to these two directions are, that their practical application still more reduces the already limited number of exploders, which can be simultaneously fired with the frictional electrical machines as found in our market at present. Hence for the safe detonation of a great number of independent charges, the use of an entirely different electrical apparatus becomes necessary.

Since even our "Standard Fuses," which of all low-tension fuses seem to be the most susceptible to frictional electricity, have only about one-third of the sensitiveness of very safe frictional fuses, it follows :

3d. *The adoption of low-tension fuses in conjunction with magneto-electric machines or voltaic batteries is the most radical way of preventing the accidents consequent on the risk in handling over-sensitive fuses.*

Again, since in the United States both magneto-electric machines and galvanic batteries have been built, which can simultaneously ignite thousands of our "Standard Fuses," and furthermore, since low-tension fuses admit of quick and accurate testing, less perfect insulation, various grouping, &c., &c., we can but advise a more liberal use of magneto-electric machines or galvanic batteries and low-tension exploders in place of frictional blasting machines and frictional electrical fuses.

In the following pages will be found *descriptions and drawings of the low-tension fuse, the galvanic batteries and battery frames as successfully used at the demolition of Hallet's Point Reef, Hellgate, on September* 24, 1876.

II.

Our Standard Fuse—A Lafflin & Rand Fuse, improved by the Writer.

Whenever a galvanic current passes through a wire it meets a certain fixed resistance, in overcoming which the energy expended is converted into an equivalent amount of heat.

This property possessed by the current is utilized in the low-tension fuses, the priming of which is fired by heating a fine wire stretched across the ends of two copper wires, whose open ends are connected with the poles of the battery.

Professor Abel, F. R. S., stated before the Society of Telegraph Engineers, in a paper relating to electrical fuses :*

"The highly permanent character of the platinum, combined with the comparatively great resistance which it opposes to the passage of an electric current, has led to its being almost exclusively used until quite recently as the material for the construction of the bridge in low-tension fuses."

And again :

"Both the German silver and platinum-silver alloy are greatly superior to platinum in regard to the resistance opposed to the passage of a current, and the heat consequently developed in given lengths of wire of a particular diameter. Comparative experiments made by me (Prof. Abel) appear to warrant the conclusion that a wire consisting of the alloy composed of about 66 parts of silver and 33 of platinum is not only superior to a platinum wire of considerably smaller diameter, as regards the resistance it offers to the passage of an electric current; but that it is also, practically, quite equal in this respect to a German silver wire of the same diameter, and is, at the same time, greatly superior to the latter in its power to resist corrosion."

Based upon the assertions of so high an authority as Professor Abel, silver-platinum wire of 0.0014 inch diameter was at once imported from England.

Our subsequent experiments with said wire proved its superiority over the materials until then used in the construction of electric fuses on this side of the Atlantic.

The most judicious length of the silver-platinum wire bridge and the selection of the fuse priming remain yet to be discussed.

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* Compare : Journal of the Society of Telegraph Engineers, Vol. III., No. 8, 1874. Notes relating to electric fuses, by Professor Abel, F. R. S,, Member of Council.

Since the sensitiveness of exploders increases with the diminution of the value of fc^2, the product of resistance of the fuse at the moment of explosion, and the square of the needful current,* with a view of selecting the most sensitive low-tension fuse, the constants f and c of a variety of fuses were experimentally found ; platinum-silver wire forming chiefly the material for the bridges, while fulminate of mercury and gun-cotton were alternately employed as priming agents in the fuses.

Although Professor Abel's directions for making gun-cotton priming (compare notes relating to electric fuses, Journal, Society Telegraph Engineers) for very fine wire bridges were strictly adhered to, both in the preparation and application of the "gun-cotton dust—fulminate of mercury mixture"—yet the technical difficulty of maintaining the pulverized gun-cotton in close contact with the thin platinum-silver wire seems not to be entirely overcome by this improvement over the usual method of pressing a small tuft of gun-cotton wool around the wire bridge, since a shaking of the "gun-cotton dust" fuses facilitated their explosion when they were exposed to the heating action of a galvanic current.

The well known French chemist, Champion, recommends for securing a permanent contact between the wire bridge and the gun-cotton priming, the application of the latter in the form of collodium. This we tried also, but found that fuses prepared in this manner required a stronger current than common gun-cotton fuses, unless especial care is taken in drying them.

Fulminate of mercury, although it explodes at a lower temperature than gun-cotton (we found the exploding temperature of the former to be 368° Fahrenheit, and of the latter 432° Fahrenheit†), yet requires being a better conductor of heat than gun-cotton, a little intenser current than pyroxilin for inflammation, when used as priming agent for low-tension fuses. On the other hand, fulminate of mercury is less hygroscopic than gun-cotton, and, owing to its greater specific gravity, packs itself better around the fine wire bridge—properties which assure the greater uniformity in the time of explosion of fuses, when exposed to the action of equal currents.

These considerations resulted in the exclusive use of fulminate of mercury as priming for our standard fuses.

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* Compare : Transactions of the Am. Soc. C. E., Vol. VI., page 186.

† Champion gives as the exploding temperature of Gun-cotton, 428° Fahrenheit ; and of Fulminate of Mercury, 392° Fahrenheit. (Compare : La dynamite et la nitroglycérine par P. Champion, Paris, 1872, page 30.)

The comparison of the sensitiveness of the different fulminate of mercury fuses led us to the adoption of a platinum-silver bridge of 0.0014 *inch diameter, and* $\frac{4}{16}$ *inch in length,* which decision is in entire accordance with the determinations of General Henry L. Abbot, U. S. E., who by his method devised for use at the School of Submarine Mining, at Willet's Point, has determined the constants of many different types of fuses, of which the following tables exhibit the data for four superior exploders.*

DESCRIPTION OF SAID FOUR FUSES.

Type.	Fine wire bridge consists of	Primed with
A.....	3-16'' platinum wire.....0.025 inch in diam.	Fulm nate of mercury.
B.....	3-16'' platinum-silver wire..0.0014 "	" "
C.....	3-16'' gold-iron wire.....0.0020 "	" "
Our Standard fuse	4-16'' platinum-silver wire..0.0014 "	" "

CONSTANTS OF SINGLE FUSES.

Type.	Resistance in Ohms.			Current in Webers to effect explosion.
	Cold.	At explosion.	Diff.	
A.....	0.72	0.82	0.10	0.45
B.....	1.49	1.57	0.08	0.33
C.....	1.87	1.96	0.09	0.34
Our Standard Fuse.....	1.90	2.01	0.11	0.28

TRIALS WITH FUSES COUPLED IN SERIES.

Type A.		Our Standard Fuse.	
Currents varying from	Per cent. fail.	Currents varying from	Per cent. fail.
1.0 to 1.2 Webers.	33	0.40 to 0.45 Webers.	67
1.2 to 1.3 "	8	0.45 to 0.50 "	44
1.3 to 1.4 "	3	0.50 to 0.55 "	33
1.4 to 1.5 "	1	0.55 to 0.60 "	17
1.5 and more.	0	0.60 to 0.65 "	8
		0.67 and more.	0

* Compare: General Abbot's paper, "Theory of Simultaneous Ignitions," No. XXXIX, printed papers, pages 147 and 148.

Since the sensitiveness of a fuse is measured by the smallness of the value of its $f\,c^2$, the resistance of the fuse at the moment of explosion (f), multiplied by the square of the needful current (c), we now have a ready means of comparing the merits of the above four low-tension fuses.

Adopting this mode, we find :

Type of Fuse.	f = resistance of each fuse at the instant of explosion.	c = current in Webers needful to fire		$f\,c^2$ =
		Single Fuses.	Fuses united in series.	
A.....	0.82	0.45	.	0.16605
B.....	1.57	0.33	.	0.170973
C.....	1.96	0.34	.	0.226576
Our Standard Fuse.....	2.01	0.28	.	0.157584
A.....	0.82	.	1.5	1.845
Our Standard Fuse.....	2.01	.	0.67	0.902289

Which means that *our Standard fuse is the most sensitive in the list of these four exploders*, which actually are the best kind of fuses at present employed in this country.

Since our fuses were to be used for submarine blasting, and likely to be exposed during three days to a considerable pressure, *experiments for the purpose of employing an impermeable fuse covering were instituted and determined after the following results were arrived at :*

1. *Nitro-glycerine is less permeating than sea-water.* Fuses, which get spoiled in water after one day's submersion, will be still serviceable after three days' exposure to nitro-glycerine.

2. *Laflin & Rand's copper shell fuses, covered at least* $\frac{1}{8}$ *inch with good gutta percha, and, previous to their employment, additionally protected with a thin* ($\frac{1}{40}$ inch thick) *coating of paraffine, will, when kept in a depth of* 40 *feet, resist the permeation of salt water, at least, four days.*

Description of our low-tension Standard Fuse. *Plate IV.*

In the construction of this exploder, three copper cylinders are used, of which the smaller ones, being open both on top and bottom, are employed for confining the priming agent – ten grains of fulminate of mer-

cury—while the larger one of the three copper cylinders is closed at the base, and when provided with the strengthening charge—ten grains of fulminate of mercury—is slipped on the copper priming case. The connecting wires pass through the larger one of the open copper cylinders; they project beyond its top nearly one-quarter of an inch, and when one-quarter of an inch apart, are secured in their position by molten sulphur. The fine bridge is soldered on the terminals, which are then squeezed together a little in order to relieve the strain on the bridge. The other of the open and short copper cylinders is pressed into the wire cup until it rests upon the sulphur filling, when it is charged with the priming and sealed by a rubber wad. The priming case being now finished, the copper cap containing the additional ten grains of fulminate of mercury is pushed on it and the whole covered with at least one-eighth inch of good gutta-percha.

For the use at the final blast at Hallet's Point, Hell Gate, our standard fuses were made up in bunches forming continuous and perfectly insulated circuits of twenty-one exploders each. The distances between the fuses while being the same for each set of twenty-one, varied from twenty to twenty-five, thirty and thirty-five feet.

The fine platinum-silver wire and the gutta-percha covered connecting wire, the latter of size 18 × 9, American gauge, were furnished, after having passed our examination, to the fuse manufacturer, the Laflin & Rand Powder Co.

Dimensions of our Standard Fuses.

Length of wire bridge	$\frac{1}{4}$ inch in the clear.
Diameter of platinum-silver bridge wire	0.0014 inch.
Length of longer copper cylinder containing wire terminals,	$\frac{7}{8}$ "
Diameter of longer copper cylinder containing wire terminals,	$\frac{3}{8}$ "
Length of shorter copper cylinder closed with rubber wad,	$\frac{13}{32}$ "
Length of copper cap containing the strengthening charge,	$\frac{15}{16}$ "
Total length of fuse before gutta-percha covering is put on,	$1\frac{1}{2}$ "
Diameter of gutta-percha covered fuse	$\frac{5}{8}$ "
Size of connecting resp. fuse wires	18×9 A. G.
answering to a copper wire of	0.040303 inch diam.
covered with one coat of gutta-percha increasing the total thickness of the connecting wire to	0.11443 inch.

III.

OUR GALVANIC BATTERIES AND BATTERY FRAMES. Designed by the writer.

Plates V and VI.

Each of the *twenty-three large plunge batteries* was built up by means of ten-cell batteries consisting of a wooden box containing ten glass cups filled with "bi-chromate solution" and a wooden bar suspending ten zinc-carbon elements. Stout copper straps solidly connected the ten elements for "intensity." The extreme elements of each ten cell battery were provided with binding screws for No. 10 A. G. wire; in addition to which nine 10-cells bars also had screw posts for each element. (This was done as a means of enabling the building up of batteries of any number of cells.) The bar was made of very well seasoned wood. Each cell, as received from the manufacturer, Mr. Chas. T. Chester, when filled with fresh fluid offered in the beginning of immersion not less than 1.98 Volts electro-motive force and a resistance not exceeding 0.12 Ohms.

Dimensions of one 10-cell plunge battery as used in the final blast.

Outside measure of wooden box containing the ten cells,	$7'' \times 7\frac{1}{2}'' \times 17\frac{7}{8}''$
Each glass cup was in the clear.....	$6'' \times 4\frac{5}{8}'' \times 1\frac{1}{4}''$
Each of the plates measured.....	$4\frac{1}{2}'' \times 6''$
and when lowered into the fluid the elements opposed,	$4\frac{1}{2}'' \times 4\frac{1}{2}''$
Distance in the clear between zinc and carbon plates of one element.....	$\frac{3}{16}''$
Size of copper strap connecting the carbon plate of one cell with the zinc plate of the adjacent cell.....	$3\frac{1}{2}'' \times 2'' \times \frac{1}{24}''$
Size of wooden bar supporting the elements.....	$17\frac{7}{8}'' \times 2\frac{5}{8}'' \times \frac{7}{8}''$
but excluding a tenon of.....	$\frac{7}{8}'' \times \frac{13}{16}'' \times \frac{7}{8}''$
on each end for guiding the bar of the plunge battery.	
Weight of one battery box containing the ten glass cups filled with the "solution".....	44 pounds.
Weight of cross-bar with its elements and binding post,	14.5 "

Forty-eight of such ten-cell plunge batteries, as described above, *were placed into each of the two large battery frames.*

Each battery frame had two tiers of shelves, which were divided longitudinally into two halves and by means of posts and guide-boards laterally subdivided into six sections, forming altogether $2 \times 2 \times 6 = 24$

partitions, or 24 divisions for two ten-cell batteries. The battery boxes rested directly on the shelves, while the wooden bars carrying the elements were suspended by means of insulated iron bolts from iron bars, which being placed parallel to the centre bracing, extended through the whole frame. As there were laterally four rows of batteries on each of the two shelves, every battery frame was provided with eight iron bars from which the elements were suspended. The bars were supported at their extremities by the front and rear wooden slides, which again could be vertically raised and lowered by means of the simple mechanical device of a rack and pinion motion. The partition boards of the frame were morticed through in order to act both as "leads" for the tenons of the wooden bars and as guides for the iron hoisting bars. Wooden chocks attached to the uprights of the frame held the slides to and allowed them to glide along the narrow faces of the battery frame. In order to facilitate the labor of raising and lowering the slides, four balance weights were employed with each frame. The suspending ropes of the balance weights worked on sheaves in the front and rear cap pieces, and were fastened to the posts of the slides. The whole being nicely equipoised, well proportioned and finished, little exertion sufficed to lower the elements into or to raise them out of the cells by simply giving the crank four-tenths of a turn. Preparatory to the final blast, the elements were hoisted up, the battery boxes were withdrawn from the shelves and filled with the standard measure of the "bi-chromate solution."

Every part having been made perfectly fitting an easy "bringing home" of the boxes was the only requirement in returning them.

When any of the elements needed repairing, the nuts of the suspension rods were unscrewed, the rods removed and the wooden bar holding the elements was taken out of the tenon slide hole by raising the bar a little more on one side. With the same facility the elements were replaced.

Dimensions of each battery frame and its characteristic parts.

Space occupied by frame	$7' \times 6'3\frac{1}{2}'' \times 11'8\frac{1}{2}''$
Interior dimensions of one two 10-cell division in lower tier	$18'' \times 29\frac{1}{2}'' \times 15\frac{1}{4}''$
Do. do. in upper tier	$18'' \times 28\frac{1}{4}'' \times 15\frac{1}{4}''$
Width of slides	$32''$
Size of each slide-post	$3'' \times 5'4\frac{1}{4}'' \times 3''$

Size of each battery frame-post	$3'' \times 5' 8'' \times 3''$
" " " battery frame-post brace	$3'' \times 4' 10\frac{1}{2}'' \times 2''$
" " " " " cap piece	$5' 2\frac{1}{2}'' \times 4\frac{1}{2}'' \times 3''$
Weight of one slide	46 pounds.
Size of each iron hoisting bar	$11' \times 2'' \times \frac{7}{8}''$
Weight of one iron hoisting bar	64.5 pounds.
Size of one suspending rod	$\frac{1}{8}''$ diam. $8\frac{3}{8}''$ long.
Diameter of spherical head of suspending rod	$\frac{5}{16}''$
Size of one cast-iron balance weight	$11'' \times 11'' \times 11''$
Weight " " " " about	326 pounds.

After the final examination and electrical testing of the cells, which gave very satisfactory results, the batteries were united into twenty-three large blasting batteries of which the "Westerly" frame, *Plate I, Fig.* 1, contained seven batteries (Nos. 3, 6, 7, 8, 9, 10 and 11) each of forty-four cells, and four batteries (Nos. 1, 2, 4 and 5) each of forty-three cells, while the four hundred and eighty cells of the "Easterly" frame were coupled in twelve large batteries, each of forty cells. The wire connection between the negative poles of these twenty-three batteries and the twenty-three brass pins of the circuit closer was then undertaken, while the screw cups of the positive poles of the twenty-three large plunge batteries and the stems of the twenty-three mercury cups were each provided with an "8-wire fork."

In order to prevent the fouling of any of the wires directly connecting with the batteries, they were secured by means of $\frac{1}{2}$-inch cotton tape to the hoisting bars of the battery frame, and also supported by lashing from the ceiling of the battery-house wherever possible.

After the drill-holes were primed, the lead-wires run to the battery-house, and the water allowed to enter the rock excavation, the groups were tested once more, labeled and classified. (The observed resistance of single groups—twenty of "Our Standard Fuses," one "lead" and one "return" wire—lay between 37.0 Ohms and 40.7 Ohms at a temperature of the water, of 63° Fahrenheit.) Groups of practically equal resistance were now united in bunches of eight, and finally connected with the "8-wire forks;" care was taken to unite the eight group branches in proportion to their joint resistance with a more or less powerful battery, viz., a 44, 43 or 40 cell battery.

Description of the manufacture of the "Bichromate Solution."—180 pounds of pure bichromate of potassa were dissolved in 150 gallons of

hot water of a temperature of 135° Fahrenheit. When the solution had cooled down to 85° Fahrenheit, 30 gallons of sulphuric acid of 1.83 specific gravity were gradually added to it, while the fluid was agitated. Specific gravity of solution 32.2° Beaumé at 160° Fahrenheit. The color of the "solution" was of a beautiful red, and unlike the mercantile article of "bichromate solution," which is of chestnut color.

The illustrations accompanying this paper are as follows:

Plates I, II and III.

Gravity Circuit Closer of J. H. Striedinger and A. Doerflinger, as used at the demolition of Hallet's Point Reef, Hellgate.

Fig. 1. Elevation of the circuit closer.

a', position occupied by movable pin plate previous to the lowering of the galvanic elements into the cells. Some of the pins are shown as connected with the wires going to the negative poles of the batteries.

a, position occupied by pin plate just before the touching off of the blast.

b, fixed plate provided with the mercury cups, of which some are shown as united by means of the wire forks, with the groups of fuses.

c, position occupied by intercepting table until the preparations were finished for the final closing of the circuits, when the intercepting table was removed. (Compare Figs. 13 and 14, Plate III.)

Fig. 2. Full top view of gravity circuit closer.

Fig. 3. Elevation of gravity circuit closer, showing position occupied by movable plate after the severing of the suspending cord by the explosion of the small cartridge or torpedo.

The pins are, by means of the mercury filling, in metallic contact with the mercury cups.

Fig. 4. Top view of circuit closer below plane *m n*.

Fig. 5. Elevation of brass pin. *a*, sectional view of part of the movable pin plate.

Fig. 6. Top view of brass pin.

Fig. 7. Elevation of mercury cup. *b*, sectional view of part of fixed plate.

Fig. 8. Top view of mercury cup.

Fig. 9. Section of brass pin.

Fig, 10. Section of mercury cup and its rubber tubing, and rubber washer insulators.

Fig. 11. Bottom view of mercury cup.

Fig. 1.

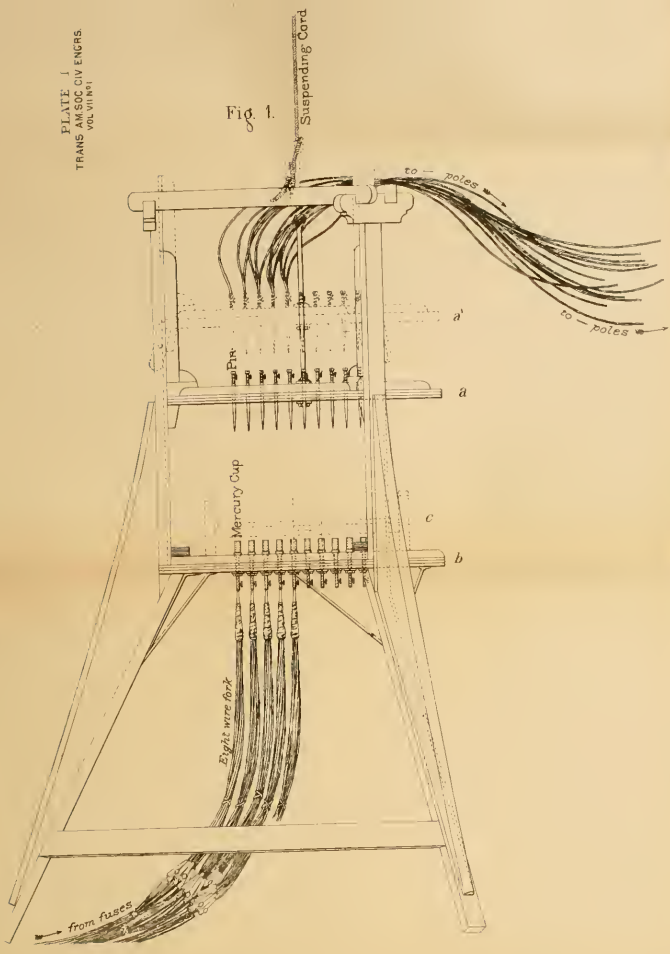

Suspending Cord
to — poles
a'
to — poles
Pin
a
Mercury Cup
c
b
Eight wire fork
from fuses

Fig 2.

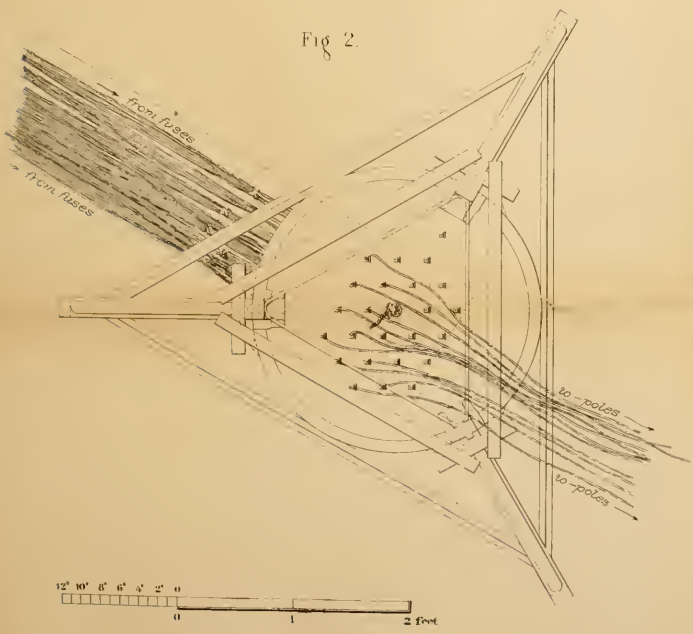

from fuses
from fuses
to - poles
to - poles
12' 10' 8' 6' 4' 2' 0
0
1
2 feet

PLATE II
TRANS AM SOC CIV ENG'RS
VOL VII No 1

Fig. 3.

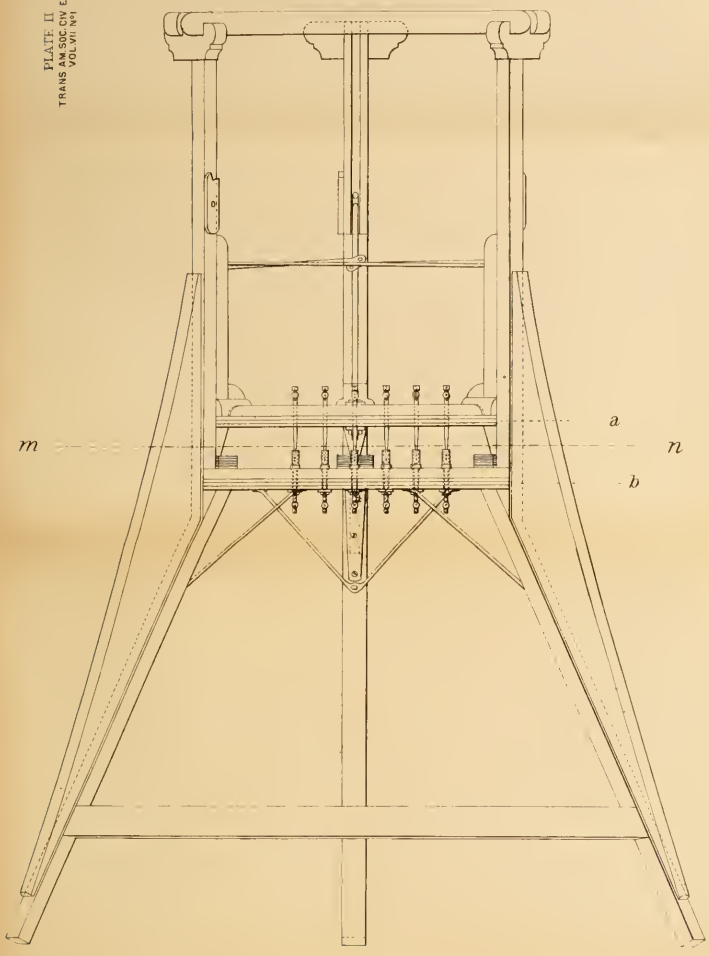


Fig. 4.

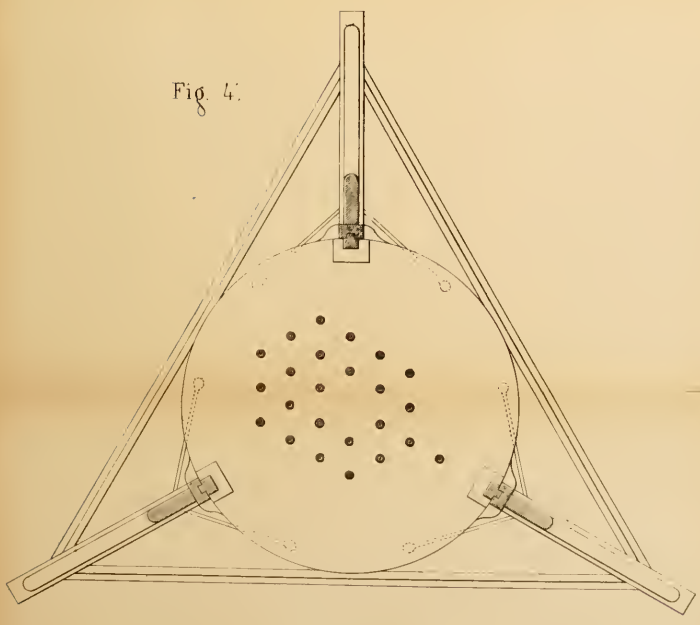


PLATE III
TRANS. AM. SOC. CIV. ENGRS
VOL. LV. 1905

Fig. 5

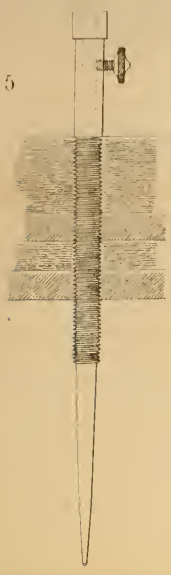


Fig. 9.

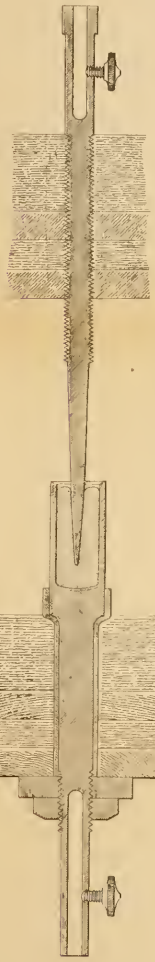


Fig. 6.

Fig. 7

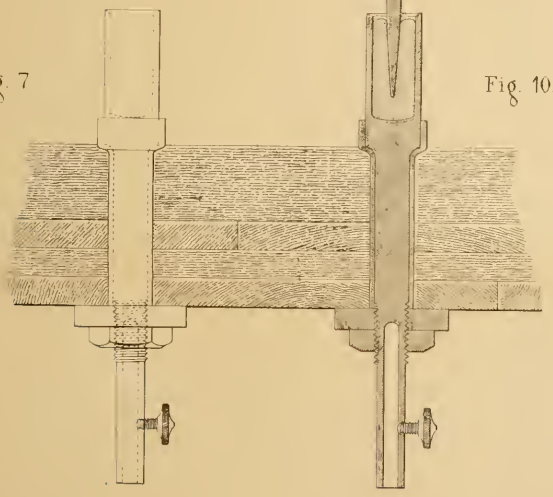
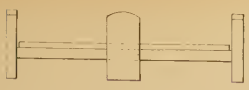


Fig. 10.

Fig. 8

Fig. 11.



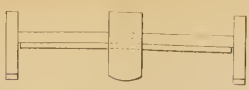


Fig. 12.

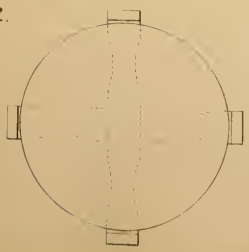


Fig 13

Fig. 1

Outside view of guttapercha covered fuse.

(Full size.)

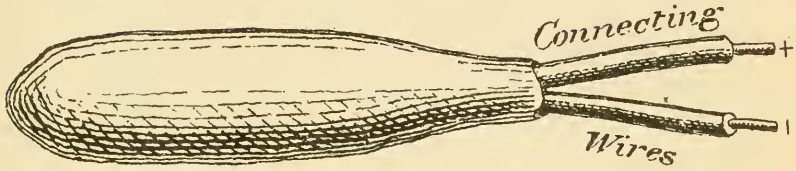
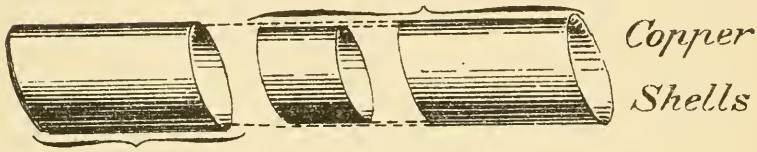


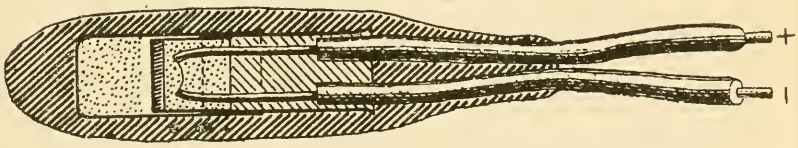
Fig. 2

Forming the copper priming case.



Containing the strengthening charge.

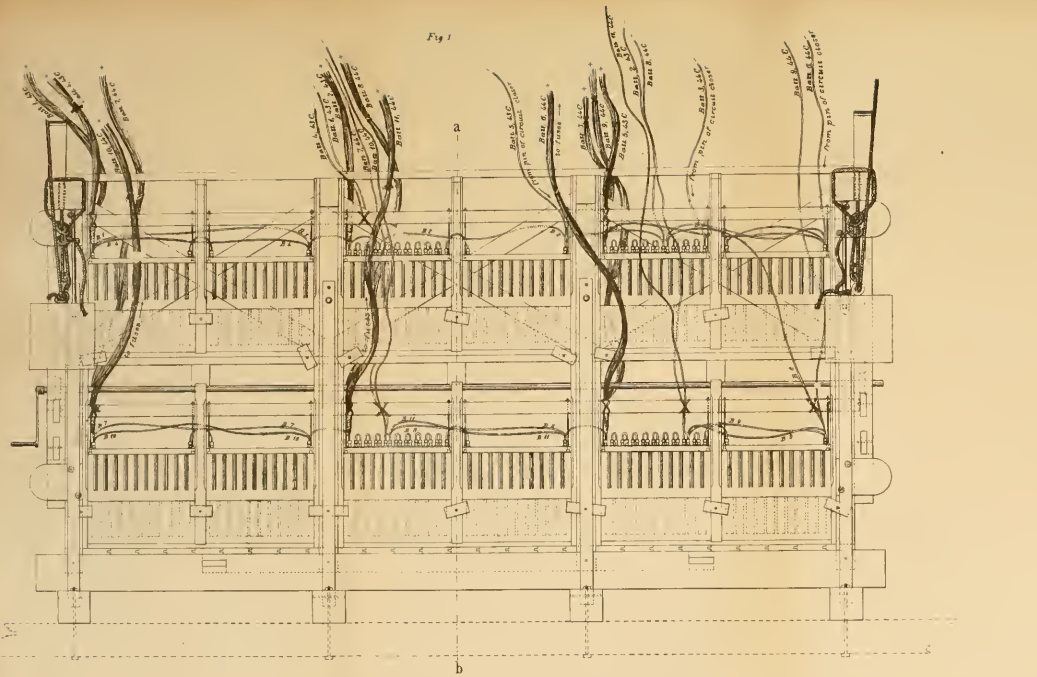
Fig. 3



Sectional view of guttapercha covered fuse

(Full size.)

Fig 1



Side Elevation

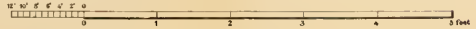
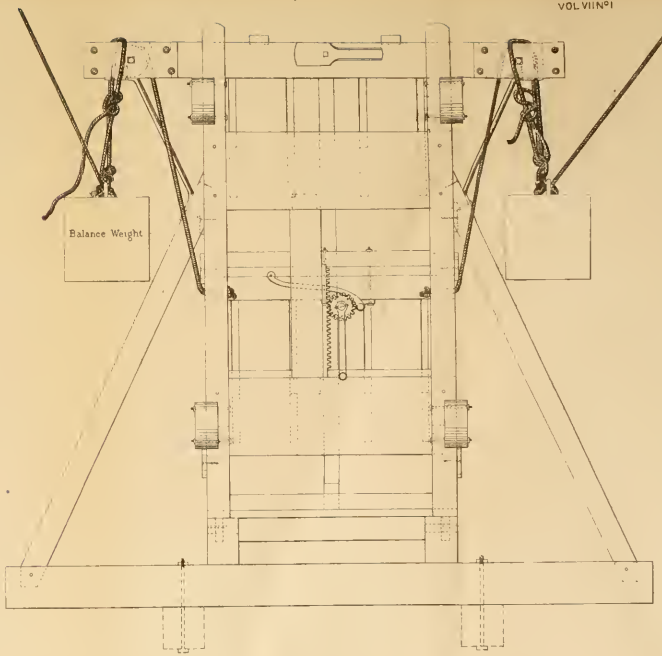
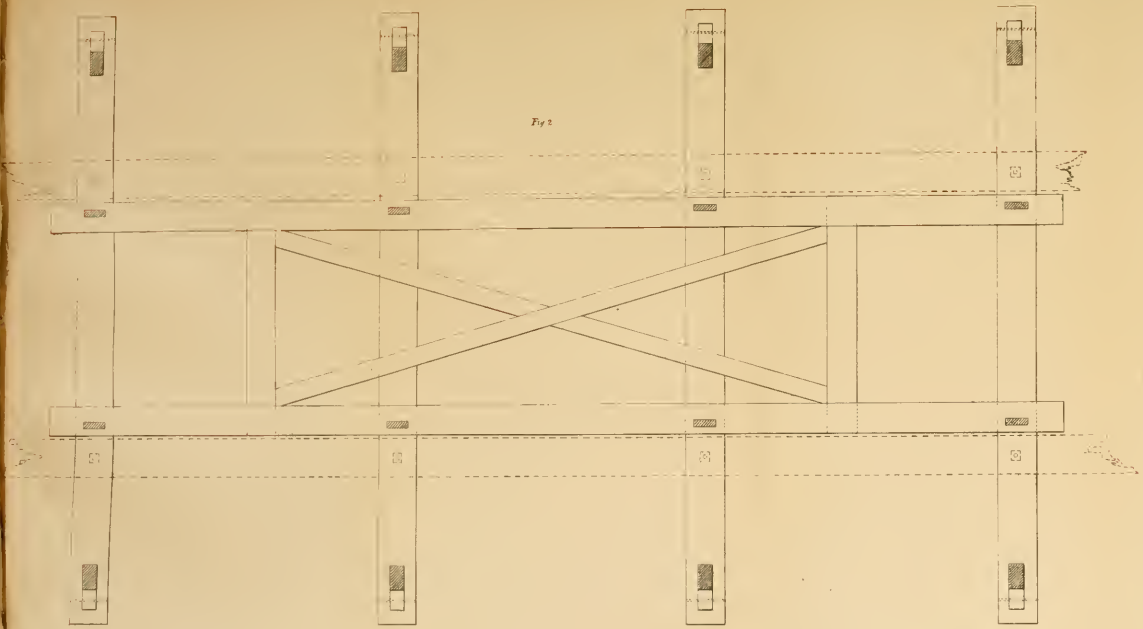


Fig 4



End Elevation

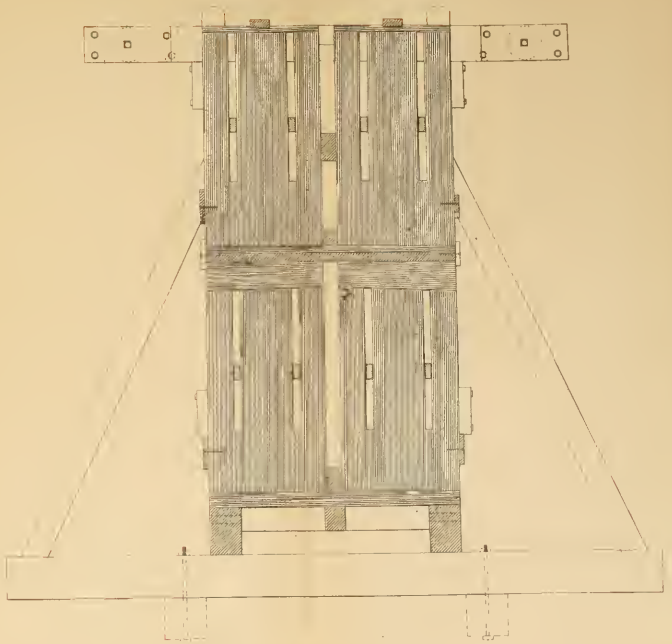
Fig 2



PLAN OF BOTTOM FRAME

0 1 2 3 feet

Fig 3



Cross Section on ab

Figs. 12 and 13. Side views and top and bottom views of intercepting table, which prevents the accidental closing of the circuits when placed between the pin and mercury cup plates. (Compare Fig. 1, Plate I.)

Plate IV.

Our Standard Fuse as used at the demolition of Hallet's Point Reef.

Figs. 1 and 3. Outside and sectional views of said fuse. Full size.

Fig. 2. Perspective view of the three copper shells employed in the construction of said fuse.

Plates V and VI.

Our Galvanic Batteries and Battery Frames as used in the final blast.

Fig. 1. Side elevation of "Westerly" frame. The 480 zinc carbon elements are united into eleven large blasting batteries.

Fig. 2. Plan of foundation timbers of battery frame.

Fig. 3. Cross section on *a b*. (Compare Fig. 1, Plate V.)

Fig. 4. End elevation of battery frame. The slides are entirely lowered.

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CLIV.

(Vol. VII.—January, 1878.)

A PECULIAR CASE OF FAILURE IN A WATER MAIN.

A Paper by D. McN. STAUFFER, C. E., Member of the Society.

READ DECEMBER 5TH, 1877.

The accompanying sketch (Plate VII.) illustrates what, to the best of my knowledge, is a unique case of failure in a water main, and is sufficiently curious to be noted.

As shown on the drawing, a hole 1 in. × ½ in. was scoured entirely through a cast-iron pipe ⅜ in. thick and four inches inside diameter. Unfortunately the break was repaired and the lead melted out of the "bell" of the adjoining pipe before an observation could be made, so that we can only get at the cause by an examination of the injured portion of the pipe.

The water flowing through this pipe is supplied from a reservoir 5½ miles distant, and at an elevation of 280 feet above the portion in question. The pressure taken at the nearest fire-plug varies from 80 to 100 lbs. per square inch, depending upon the time of observation and the amount of water being drawn off. The soil in which the pipe is laid contains much fine, sharp sand, and it is the presence of this sharp sand, we take it, that accounts for the mischief.

The hole was in the *top* of the pipe, and is evidently the result of a scouring action ; there is no sign whatever of a flaw in the iron, which is of an excellent quality.

The cause was apparently as follows : The lead used in making the joint was, very probably, carelessly poured and as imperfectly caulked, leaving a weak spot in the joint at the "pouring gate," on top of the pipe.

The lead giving way under the pressure, allowed a small jet of water under an average pressure of 90 lbs. per square inch to strike the pipe just outside of the bell. The soil above, mainly sharp sand, continually caving in from the action of the water, furnished an excellent grinding material, and the jet was the active agent, thus forming, in fact, a natural "sand-blast," exactly similar in effect to the machine so usefully applied by Mr. Tilghman. The outside of the pipe was brightly scoured within the limits indicated by the dotted lines on the drawing, and grains of sharp sand were still imbedded in the pits shown in the sketch. Just how the grinding material got *under* the "bell," as it evidently did, is the one thing not easily explained, as there is no evidence of any sand *within* the pipe. Four days before the water burst through the injured pipe, this joint was laid bare in making some repairs, and there was no leak then apparent, so that this $\frac{3}{8}$ in. of cast-iron must have been scoured through *within* that time.

DISCUSSION

On a Peculiar Case of Failure in a Water Main.

Mr. George S. Greene, Jr.—I think this not a very uncommon case of failure. Mr. A. W. Craven, when Chief Engineer of the Croton Aqueduct, had in his office specimens of pipe cut by sand and a current of water. The explanation given in the paper by Mr. Stauffer appears fairly to account for the effect produced, although the time, four days, seems somewhat short for cutting through a pipe $\frac{3}{8}$ in. thick.

Mr. W. H. Paine.—At the caisson for foundation of the Brooklyn Bridge, sand was blown out through a pipe $3\frac{1}{2}$ in. diameter (a short piece at the lower end was only $2\frac{1}{2}$ in. diameter). At the upper end an elbow was necessary to properly direct the stream of sand. The iron in these

elbows was $\frac{3}{8}$in. thick. Under a pressure of $34\frac{1}{2}$ pounds, the greatest pressure, the stream of sand cut through every kind of iron tried except Franklinite, in one half hour. Franklinite stood longer.

Mr. C. L. McAlpine.—A similar tube was used at the Harlem River Bridge for months, at about the same pressure as that mentioned by Mr. Paine, but with no perceptible wear of the pipe, although a large quantity of sharp sand, gravel and stones was ejected with a force that sent stones through the atmospheric air to a distance of 60 feet.

Mr. Wm. J. McAlpine.—I have closely examined the pipe in question, and with a new, sharp file.* I find the edges of the hole to be a white, chilled iron, and other parts of the pipe of materials of various grades, from very soft to very hard iron. In some places I have picked out some of the material with the point of a pocket knife. The pipe was undoubtedly a defective one, and at the place in it where the leak occurred, scoria or other imperfect material with no more consistency than coke, overlaid the very thin sheet of hard iron. The latter was evidently *too weak* to withstand the internal pressure of the water.

The theory of the author of the paper is that the water that produced the scour escaped from an adjoining bell-joint. The action of the leakage water, under the circumstances, would make two short, nearly right angle turns, and after finally escaping, would be projected in a nearly horizontal direction parallel to the pipe, and thus encountering a rounded surface of iron on one side and the natural earths on the other, as mentioned by the author, its force would be so diffused that it could only act upon the weaker material—the sand, and would have no force left to act upon the iron.

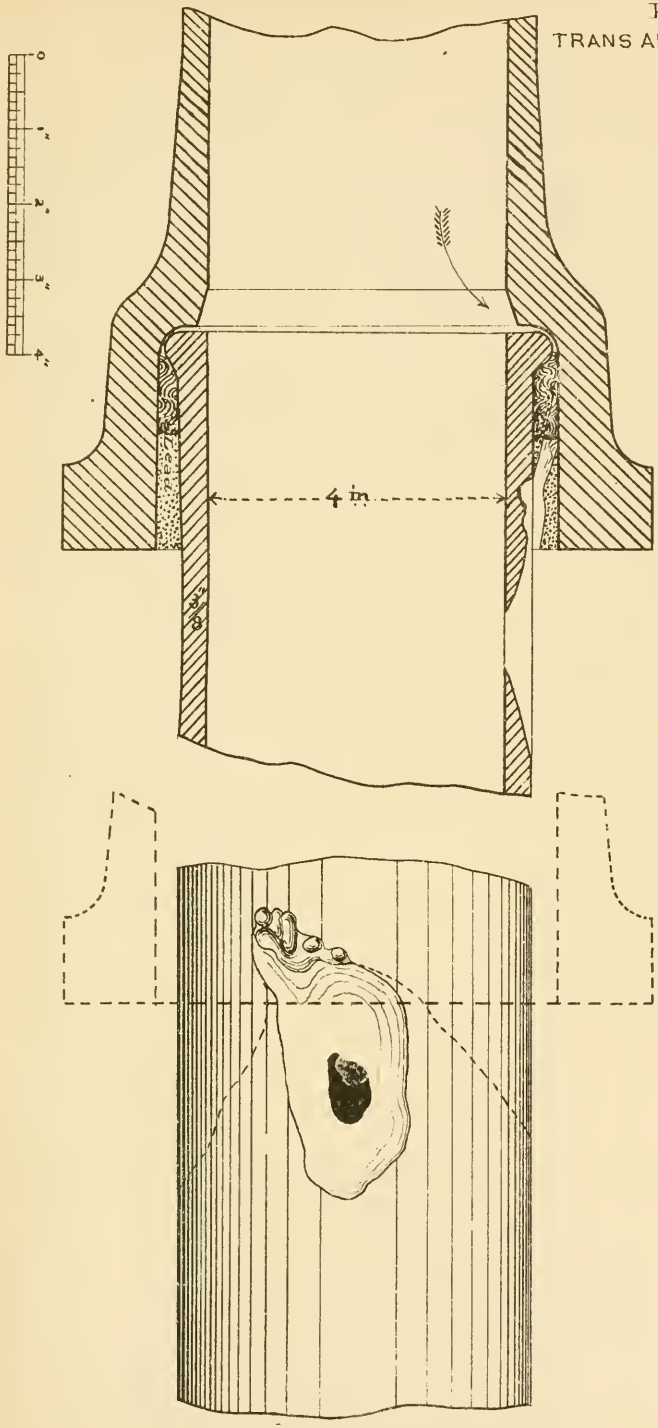
If the iron pipe contained scoria also, as the surface showed, it would have but little coherence or strength, and its surface might be rapidly worn away, and produce the result which the specimen exhibits. This specimen evidently had not sufficient strength to resist the pressure of water from the interior of the pipe to which it is said to have been subjected.

I differ entirely from the author's theory that the hole in this pipe was or could have been produced by or on the principle of a "sand blast," so called.

---

* December 19th, 1878. The piece of pipe containing the hole as described in the above paper, was exhibited.

PLATE VII
TRANS AM. SOC. CIV. ENG'RS.
VOL VII No I



ERRATA.

In paper (CLII, Vol. VI), entitled "Notes and Experiments on the use and testing of Portland Cement," by William W. Maclay, C.E., in Table 20, Page 363, the last five columns of Analyses, Nos. 7, 8, 9, 10, and 11, and the Remarks, should read, as follows :

7	8	9	10	11	
English Portland.	German Portland, Bonn, "Mining and Smelting Union."	German Portland, Kratt, and Saulich.	American Portland, "Saylor's from Coplay, Penn., U. S."	American Portland, "Saylor's from Coplay, Penn., U. S."	REMARKS.
Hopfgartner.	Hopfgartner.	Feichtinger.	F. A. Cairns. 1877.	F. A. Cairns. 1877.	
55.06	57.83	55.28	56.35	61.05	In Analysis Nos. 10 and 11, alkalies were undetermined. The figures opposite Sulphate of Lime, Ca. So_4 in these two Analyses, represent percentages of Sulphuric Acid, So_4.
22.92	23 81	22.86	21.12	21.18	
8.00	9.38	9.03	11.42	8.50	
5.46	5.22	6.14	1.73	2.50	
0.77	1.35	1.64	4.92	3.57	
1.13	0.59	0.77	.....	.....	
1.70	0.71	.....	.....	.....	
1.75	1.11	3.20	1.73	2.19	
2.27	.....	1.08	.....	.....	
acid.			2.67	0.93	
			.....	.....	

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CLV.

(Vol. VII.—February, 1878.)

THE IMPROVEMENT OF THE SOUTH BOSTON FLATS

BY THE HARBOR COMMISSIONERS OF THE STATE OF MASSACHUSETTS.

A Paper by EDWARD S. PHILBRICK, C. E., Member of the Society.

Presented February 20th, 1878.

It was found, some twenty years since that the upper harbor of Boston, between the end of Long Wharf and the Castle Island narrows, had become so much shoaler during the past century, that considerable inconvenience had been occasioned to the commerce of the port.

Seeking relief from this steadily increasing evil, the city government in 1860, by Hon. F. W. Lincoln, Mayor, called in the aid of a commission of experts whom the President appointed for the purpose, consisting of the Chief Engineer of the United States Army, Gen. Jos. G. Totten, the Superintendent of the United States National Observatory, Admiral Chas. H. Davis, and the Superintendent of the Coast Survey, Prof. A. D. Bache. These commissioners undertook by careful hydrographic surveys and researches based thereon to account for the changes that had taken place, and to recommend such action as might be advisable to remedy the evils. They embodied their researches and advice in ten reports to the city government, of which a short abstract is given below; but owing to the magnitude of the works recommended it was considered to be more appropriate for the State and Federal Governments than for the city alone to carry them out.

In pursuance of this view, the Federal Government has accomplished important work in the lower harbor along the line of the main ship channel. The State Legislature also passed an act in 1866, constituting a Board of Harbor Commissioners to whom was committed the interests of the State in guarding against all encroachments and deterioration from

whatever causes in all the harbors of the State, and with particular reference to remedying the shoaling of the upper harbor of Boston by the works recommended. The former Board of Federal officers was retained as an "Advisory Board" to co-operate and advise in these important improvements. On the death of Gen. Totten, his place was filled by his successor, Gen. Delafield, Chief Engineer of the United States Army, and on the death of Prof. Bache, his place was filled by Prof. Benj. Pierce, Superintendent of the Coast Survey. Prof. Henry Mitchell, assistant in the Coast Survey, was added to their number.

It was found by these commissioners that like many growing cities situated on navigable waters with shoal margins, Boston had been gradually built out into the tide water, by the reclamation of these margins for wharves, streets and buildings, so that the densely peopled portion of the city occupies now an area about half of which was once covered by the daily tides. This change had produced a marked effect upon the tidal currents of the upper harbor. It changed the line of the shore so as to alter the direction of the currents in some places, leaving former channels to be slowly filled by deposit of suspended matter, while the loss of the tidal prism, displaced by the filling of reclaimed margins had seriously diminished the volume and scouring force of the flow in the immediate vicinity of and below the city.

If we draw a line across from Deer Island to Point Allerton, connecting the headlands at the mouth of the harbor (see Chart, Plate VIII), we shall enclose an area subject to tidal flowage of about forty-five square miles, with an average tide of ten feet. Thus an enormous mass of water passes these headlands in its flux and reflux every six hours. The loss of the tidal prism on the surface formerly flowed and now reclaimed does not sensibly affect the volume of water daily passing this strait, which is some three miles wide, but that loss *does* materially affect the volume flowing through the part of the harbor above Castle Island, where the deterioration had taken place. The volume of fresh water flowing into the harbor is never large, and the depth of its channels is only to be maintained by the tidal scour. The tidal action, however, serves to intensify the power of the land water by damming it back one-half the time, to be delivered during the ebb with double its average volume. Tidal currents also give a definite resultant in one direction, not canceled by the return flow, owing to the configuration of the shores, which often throw the flood and ebb currents in different paths. Even when following the same path, which is sometimes the case, the ebb is generally

more efficient in scouring, not only from its being reinforced by the land water, but because its course is *concentrative*, accumulating velocity as it goes, while that of the flood is *dispersive*, losing velocity as it scatters laterally, over the flats on either side the channels.

There is one point, however, in Boston harbor where the flood was found to be a stronger current than the ebb, viz., above the Castle Island narrows. But before arriving at a point opposite East Boston, the flood current loses force by lateral dispersion, and the ebb is as usual the stronger. Thus the flood current being checked here, tended to deposit suspended matter.

The ebb tide also, in issuing from the strait between Boston and East Boston is suddenly checked by several local causes, all combining to produce loss of velocity and consequent deposits. Among these causes are the following: (*a.*) The large lateral expansion of the ebb, and consequent dispersion over the area between South Boston and East Boston. (*b.*) The want of accord between the ebb tides of the basins of Charles and Mystic rivers. The latter discharges most of its tidal prism from a near point, and having but little area to deliver water from after half ebb, owing to its extensive flats left bare at that time, gives most of its water to the harbor early in the ebb flow, and has but little left for the latter half of the ebb. The basin of Charles river however is further up stream than that of the Mystic, while the numerous pile bridges which cross between Boston and its northern suburbs oppose by over eleven thousand piles the flow of the current to a marked extent. The result is, that the ebb from the Charles runs with most force after that from the Mystic is mostly expended, and continues to run with force through these bridges for some time after the flood current has entered the upper harbor. Thus these two important basins lose much of their efficiency for tidal scour by lack of unity in their action. (*c.*) Another, though a minor agent, in checking the ebb at this point is found in the direction of the ebb from the south bay which debouches into the upper harbor by Fort Point channel in a direction almost diametrically opposed to that of the ebb from the northern basins, serving thereby not only to cancel its own momentum but to check as far as it may that of the other currents.

Reasoning from the above state of things which was deduced from their surveys, the Board of Special Commissioners recommended at an early day the enclosure of the South Boston flats by a wall extending along the southerly side of the main ship channel towards Castle Island,

and connecting with the east side of Fort Point channel by an easy curve, while the western side of this channel near its junction with the harbor was to be built out in a parallel curve, as shown on Plate IX. By this means the ebb current from the south bay would be prevented from wasting its force and that of the northern channels, and would be led by the curved bank on its west side to follow the line of its eastern side, along the new wall, till its direction should essentially contribute to, rather than check, the velocity and momentum of the ebb in the ship channel. Moreover, the walling in and reclamation of this extensive area of flats on the South Boston side would so far prevent the former dispersion of the ebb, as to add vastly to its scouring power in the ship channel. The construction of a similar wall along the north side of the ship channel from East Boston towards Governor's Island was also discussed, passing along where Bird Island had formerly existed, and thus serving to prevent the undue dispersion of the ebb tide on this side. The efficiency of such a remedial measure was not doubted, but there was too little prospect of recouping the cost of such a work, by the value of the lands reclaimed for commercial uses, to justify such an undertaking. The prospect of a demand for such lands on the South Boston side was, however, considered sufficient to warrant the enterprise, and in 1868 a tract of some twenty-five acres on the east side of Fort Point channel was sold to the Boston Wharf Company to be walled in and filled. The Harbor Commissioners being authorized also, made contracts in 1868 on behalf of the State for walling in and filling the portion of these flats north of those sold to the Boston Wharf Company, nearest to and along Fort Point channel, for a compensation in a part of reclaimed lands; but as the terms of the contract did not meet the approval of the Executive, the subject was dropped. In the year 1873, an appropriation of money having been made for the purpose by the Legislature, the Harbor Commissioners made contracts for the building of about 720 feet of light wall on piles along the east side of Fort Point channel from the lands filled by the Boston Wharf Company, northward—and thence for the building of a heavy sea wall around the curve as shown on Plate IX, to the boundary line of flats sold to the Boston and Albany Railroad Company, with the filling in of about twenty-five acres of land enclosed.

This last-named corporation, having purchased a tract of about 50 acres on the easterly side of the above, agreed to wall in the same along the front or harbor line and fill in behind the wall the whole of said 50 acres, reserving such portions as might be needed for docks or tidal

basins for the use of vessels. The filling and walliug was to progress in connection with the improvement of the 25 acre tract improved by the State, and contracts were made by the railroad company with the same parties who contracted for the work done by the Harbor Commissioners at similar prices and subject to similar plans and specifications. The work then contracted for has made some progress and the work of improving the State's tract of 25 acres has been finished. That undertaken by the railroad company is still in progress. The material for filling up to grade 13 above mean low water was to be of clay taken from the harbor between the walls and the main ship channel, by dredging to a level of 23 feet below mean low water. Three feet of clean gravel ballast was to be, and has been placed on this clay, raising the improved tracts to a level of 16 feet above mean low water, or 2 feet above high water of extreme spring tides.

The following specifications describe the work done by the State :

Light Sea-Wall.

Section 1. Said wall shall be built in such location as shall be marked out by the Engineer of the Board of Harbor Commissioners, previous to the commencement of operations by the contractor ; and the contractor shall preserve the location of said line by driving piles to mark the location of the wall permanently.

The trench shall be dredged for the wall, under the direction of said Engineer, to a depth of two feet below low water spring tides.

The foundation piles to support the wall shall occupy a space nine feet wide, having five piles in parallel rows, said rows to be two and one-half feet distant from centre to centre of each row.

All piles shall be driven into the hard clay stratum to the satisfaction of the Engineer of the Harbor Commissioners. The piles to be in diameter not less than ten inches at low-water mark spring tides, at which point they are to be sawed off level with each other.

On the top of the piles are to be spiked two layers of spruce plank twelve inches wide and three inches thick, lying at right angles with each other. The space between the heads of the piles for two feet in depth to be filled and well rammed with stone chip ballast or oyster shells.

The wall from low water of spring tides to the top of the coping stones or grade sixteen, shall be eighteen feet in height, with a true batter front and rear. The wall shall be nine feet wide at the bottom, five feet wide at the top, including an offset of one foot for a resting

place for cap to support the ends of platform joists; to be constructed of good quality granite rubble wall stones, from eighteen inches to two feet thick, with sufficient headers to secure the stability of the wall, well bonded and pinned throughout.

The rear of the wall shall be ballasted with oyster shells, from the back of the wall to a line commencing at a point two feet in rear of the back of the top of the wall, and extending in a slope of forty-five degrees to the base of the wall, as shown on annexed plan marked X.

At the end of the wall a flank wall shall be built to connect this wall with the adjoining heavy sea-wall, according to the direction of the Engineer of the Board of Harbor Commissioners.

This wall to be commenced within thirty days after notice that the location of the wall is made, and the work to be prosecuted without delay to its completion, and completed on or before the first day of May, eighteen hundred and seventy-four.

Heavy Sea-Wall.

Sec. 2. The base of this sea-wall shall be built on a line parallel to said modified line, and one foot within the same as aforesaid and in such location as shall be marked out by the Engineer of the Board of Harbor Commissioners, previous to the commencement of operations by the contractor; and the contractor shall preserve the location of said line by driving piles to mark the location of the wall permanently. This sea-wall shall be built in accordance with the plan marked XI, hereto annexed.

The trench for this sea-wall shall be excavated to the satisfaction of said Engineer, forty-five feet in width at the bottom, which shall be as nearly as practicable a level surface. The depth of the trench shall be at least twenty-three feet below mean low water and always to hard bottom.

This trench is to be filled with broken quarry stones of mixed sizes, none less than seventy-five pounds weight, thrown in and deposited in regular layers of not over four feet each in depth, and each layer is to be placed compactly by divers with bars before depositing the next layer.

This filling is to be forty-five feet in width at the bottom and for the lower three feet of its depth, thence sloping inward on each side with a slope of one and a half horizontal to one vertical for a further depth of nine feet, where, at a level of eleven feet below mean low water it is to

be eighteen feet in width. The filling is to be levelled up here with smaller chips of quarry stone to receive the wall, and the outer or harbor slope is to have the interstices well filled with similar chips.

The wall to the height of one foot below low water shall be built in quarry face dimension stone of granite, laid in courses of two feet rise each, by the aid of submarine divers. The courses shall be laid alternately, entirely with headers and stretchers, the bottom or first course being headers. Each stone shall be at least four feet, and not more than ten feet long, at least eighteen inches wide, and exactly two feet rise, fitted to one inch joints, square ends and out of wind.

The wall shall be compactly laid in a substantial and workmanlike manner, with fair and close outer face. Stones shall be laid so as to break joints everywhere, with good and sufficient bearing upon the beds without pinners.

The base of the wall shall be fourteen feet. The height of the wall to one foot below mean low water, ten feet, and the thickness of the wall at top, eleven feet four inches.

The wall from one foot below mean low water to the top of the coping stones, or grade sixteen, shall be laid with dimension stone, in cement. The courses shall be laid with headers and stretchers, with not over ten feet interval between the headers, and have two feet rise, with the exception of the coping course, which shall have a rise of three feet, and be entirely of headers. The stretchers shall be at least four feet long, and the headers shall not be less than six feet long from face inwardly. The batter of each face shall be two inches to the foot.

The base of this wall shall be nine feet eight inches; the height, seventeen feet; and the thickness at the top of the wall, five feet.

The back of the whole of the heavy wall from top to bottom shall be ballasted with clean gravel, cobbles or oyster shells, resting at a slope as steep as they will stand, or forty-five degrees, and tapering to nothing at the top of the wall.

This wall shall be commenced by the first day of May, 1874, and finished by the first day of August, 1875.

Sec. 3. Spaces in said walls for docks, or purpose of filling by scows, or any other purpose, may at any time be reserved, permanently or temporarily, by said Board of Harbor Commissioners, upon notice before the structure of the wall is begun in any such space, and where such space is permanently reserved, it shall be filled by a strong bulk-head, to the satisfaction of the said Engineer.

Filling.

Sec. 4. The parcel of flats to be filled is situated at the easterly junction of the main and Fort Point channels in Boston harbor, bounded southwest by the flats of the Boston Wharf Company, and southeast by flats sold to the Boston & Albany Railroad Company, and containing about a million square feet, more or less.

The filling must be up to grade sixteen. Up to grade thirteen the filling must be with materials dredged from the mouth of Fort Point channel below the line of Oliver street extended, and from that part of Boston Harbor represented by the space colored red on the "Plan for the occupation of flats owned by the Commonwealth in Boston Harbor," appended to the sixth annual report of the Board of Harbor Commissioners, and other portions of Boston Harbor above a line extended from Buoy No. 11, at right angles with the line of said sea-wall, on the main channel. Such portions of Boston Harbor are to be dredged to a uniform depth of twenty-three feet at mean low water. Such portion of Fort Point channel is to be so dredged that the bottom shall uniformly and gradually slope from a depth of twelve feet at mean low water at the line of Oliver street to a depth of twenty-three feet at the southwest border of the area represented by the space colored red on said plan. The residue of the filling to grade sixteen must be with good clean gravel. The whole filling to be finished on or before October 1st, 1876. Where the said sea-walls to be built around said flats shall not be built so as to furnish the requisite protection to the filling, temporary bulkheads must be built for that purpose, as required by the Board of Harbor Commissioners. Spaces required for docks may be reserved at any time from filling by the Board of Harbor Commissioners.

Location and Construction of Dock.

It was concluded during the progress of the work to construct a dock or tidal basin on the portion put under contract, the location and size of which is shewn on Plate IX. This plate shows by a heavy black line the location of the walls constructed up to this date along Fort Point Channel and around to the second dock.

The wall around the docks is classed as "Light Wall," being of the same construction as that on the east side of Fort Point channel. It is founded on five rows of piles driven from 20 to 30 feet into the bottom, about 10 feet of which is a stiff clay, affording a satisfactory foundation

for vertical loads, but the superficial part of the deposit was generally quite soft, affording but little lateral support. A section of this wall is shown on Plate X. The timber platform shown on this section has not yet been constructed. This structure is intended to provide width for the slope of the clay between the deep water of the berths in its front and the top of the piling under the wall, which is only two feet below low water. If the piles were exposed to the water, they would speedily be destroyed by worms.

Since this slope near the mouth of the docks is more exposed to the erosion of waves and currents than elsewhere on the light walls, the clay could not be depended upon here to stand at so steep a slope as elsewhere, so a greater width is here required for the platform. A width of 20 feet from the bottom of the wall is provided in the interior part of the dock, and as it is desirable to keep the front line of the platform straight, or, at any rate, not to allow it to encroach upon the width of the dock, the walls are deflected back near its mouth, so as to allow a width of 40 feet at the outer ends. If the platform had been here limited to a width of 20 feet, and the dock walls built straight, it would have been necessary to start the foundation of these walls several feet deeper ; and as the stone could not have been so laid without submarine divers, such a plan would have largely increased the cost, without adding to the stability of the permanent work. The greater width of the platform is an increase of the amount of work subject to renewals, but does not affect the permanent portions of the works, except as here stated. The walls around this dock were constructed in 1876, the foundations having been largely prepared during the previous winter.

In Table A will be found a record of the actual settlement of these light walls, averaging about 2 inches up to this date, being chiefly due to the indentation of the bottom stone into the plank, and the springing of the plank to get a complete bearing on each pile head.

Owing to the rapid filling of certain portions of the space during the last season, slight forward movements took place, as follows : At a point about 200 feet from the southwest corner of the dock it moved forward 6 inches. At a point on the east side of the dock, about 25 feet from its junction with the heavy wall, it moved forward 6 inches. This motion did not appear to continue in any case beyond the period during which the semi-fluid clay filling was expelling the water with which it had been mixed by handling, and which floated out of it shortly after being dumped.

The Fort Point channel wall was continued with the same light section till it reached a depth of some 19 feet of water at low water in the channel which was dredged along its front, with an increasing depth as it approached the open harbor. No greater depth than this could be safely maintained along the front of a wall of this light class, unless greater width were given for the timber platform, to provide for the slope of the bottom upward from the channel towards the wall, to cover the piles. For this reason, and for others connected with the tidal currents, the point indicated by the offset on the plan (Plate IX) was selected for beginning the heavy wall. The light wall was set back 25 feet at the bottom from the harbor line, to give room for the platform and the slope under it, but the heavy wall, being founded 23 feet below low water, is built on the harbor line.

This light wall on Fort Point channel was begun in March, 1874, the foundations having been partly prepared during the previous winter. It was completed in the autumn of the same year, except for a short distance where it connects with the heavy wall beyond by a spur running out to the harbor line.

The settlement of this light wall is recorded in Table A. Early after its completion this wall was filled up to grade 13 with clay, and a large pile was left temporarily at a higher level near the beginning of the curve. Directly afterwards a forward movement of the wall was observed, about a foot in amount, and tapering out in about 200 feet of length each way. The pile of clay was soon removed by spreading on to adjacent spaces, and no further movement has been detected here since. The coping had been considerably disturbed by the hoisting of clay over it, and was reset in 1877, on a straight line, leaving the offset below the coping of slightly irregular width.

A tabular statement of the results of the pile driving for this wall and the dock wall is appended, which may serve as a criterion from which to judge of the character of the material, and to compare with similar material in other works to be constructed. See Tables *J* and *K*.

The Heavy Sea Wall west of the Docks.

From the end of this light wall, for a distance of 803 feet along the coping, around the curve to the first dock, we have a heavy sea wall, a section of which is shown on Plate XI.

The plan originally proposed for this wall is shown on Plate XII, except that no ballast was then provided behind or under it. It was

approved in 1868 by Major-General J. G. Foster, George R. Baldwin, James B. Francis, and T. Willis Pratt, four engineers of high standing. It was the plan contemplated in the contracts above alluded to as having been made at that time, which were not approved by the Executive.

Upon subsequently examining the character of the foundation on which this wall west of the dock was to rest, it was found that some parts of the clay bed were much softer than others, to such a degree that it was feared an unequal settlement might occur if this plan were to be carried out, so as perhaps to endanger its stability. Moreover, the slippery nature of the clay bottom might lead to its being pushed bodily forward when loaded by the filling behind it. It was found that a wall built on a foundation of broken stone, as shown on Plate XI would cost rather less than if built entirely of dimension-stone, while the inspection necessary to secure good work would also be less difficult. Moreover, though the weight of this broken stone would force the lower portions into the clay unequally, because of its unequal softness, thereby causing an unequal settlement when first applied, this unequal settlement would, it was thought, reach its limits before imposing the weight of the dimension-stone, so it could be levelled up after such settlement. After consultation with Mr. James B. Francis, C. E., this plan with the broken stone base was therefore adopted for the portion of the wall under consideration.

As the foundation of this wall is at the same level with the harbor floor in its front, it might be exposed to undermining if any scour were to occur along its base. But repeated observations have shown that there is a slight but constant accretion of mud here, so that we only had to be careful to get every part of the foundation down to the proposed grade.

This work was begun by depositing the broken stone after dredging the trench, in April, 1874, and nearly the whole mass, or about 12,000 cubic yards, was deposited during that season, and partly levelled up after waiting for its settlement. Large stones were deposited at first, and their interstices filled by smaller ones placed roughly by divers as specified. It was found that some inconvenience arose in complying with the smaller limit of 75 lbs. weight named in the specifications, and this point was waived, stones being received of any size, provided they were of such a mixture of sizes as to secure compactness.

This work received the repeated inspection of divers employed by the State, as well as the occasional personal inspection of the assistant

engineer in charge, Mr. Joseph O, Osgood, whose reports were far more reliable and intelligent than those of ordinary divers. The success of the structure is largely due to these precautions, without which such a foundation would be likely to give much trouble by subsequent unequal settling.

Previous to beginning the work of laying the dimension-stone, this foundation was carefully levelled up to the proper grade, as follows: Before depositing the broken stones, guide piles had been driven in the line of the upper angles of the slopes of the foundation, both outside and inside the future wall. These were driven in pairs, about 30 feet apart between pairs, the inner one of each pair being located by triangulation and the outer one measured out from it. A line of planks, running lengthwise the wall, was spiked to each row, so the upper edge of the plank should be at the level of 11 feet below low water, the grade for levelling this material. Iron straight-edges, some 20 feet long, were then laid across from plank to plank, and the stone chips applied to bring the material up to the plane thus indicated. The front row of plank was also used to support a straight-edge resting on the front slope, with a triangle on it of the proper angle, carrying a level on its upper edge, for dressing this slope to the prescribed plane. It was of course important to fill all hollows in this slope which might lead to the slipping out of the material from under the wall, and all angular stones projecting beyond the plane so as to threaten injury to vessels, were either taken out or filled around with small stones.

Alignment of the Heavy Walls.

Since these walls were located about a quarter of a mile from *terra firma*, and were to occupy a definite line prescribed by the Harbor Commissioners on curves of 908½ and 2368½ feet radius, considerable pains were required to set out and maintain these lines during the construction. The surface, when the work began, was nearly bare at low water, but covered some twelve feet at high water, and was to be dredged some 20 feet deeper. The following method was adopted. Clusters of piles, four or more in a place, were driven about one hundred feet apart, and fifty feet back from the line of the wall, so as to be out of the way of the foundation trench. The piles in each cluster were drawn together by bolts at the top. One of these clusters, or dolphins, was located at the beginning of the curve of 908½ feet radius and one at its centre, built larger and firmer than the others, and carrying on its top a small plat-

form on which a transit could be placed. The transit at the centre of the curve measured off the angles between radial lines marked on those dolphins around the circumference, and another transit on the dolphin at the beginning of the curve, starting from a tangent laid off in succession half the corresponding central angles intersecting the radial lines previously established; these intersections thus became successive points in a circle fifty feet inside the line of the wall and concentric with it. Whenever a line was needed on the wall, the measurement of fifty feet in range with the centre, from the points established on any two of the dolphins, would readily give it, the lengths of the chords between the dolphins always defining the length of the corresponding chords on the wall line. These dolphins were frequently knocked about by tug-boats and scows, and during the first winter were badly treated by the ice, requiring frequent renewals of the points on them, as well as renewals and repairs of the dolphins themselves.

The line for the dimension stones was given as follows: Points were made upon temporary skeleton stages, spiked to the guide piles opposite each dolphin by measuring out from the same. A heavy plummet was swung from these points on to the foundation below, where a diver stood ready to place a heavy stone and drill a hole in it for a bolt under the plummet. A line was then drawn on the chord between any two of these bolts, and the appropriate ordinates set off for intermediate points by the diver, according to a list furnished him, whenever he wished to align the face stones.

The successive courses were laid by making offsets from the one last laid, verified occasionally by reference to the dolphins.

During the month of August, 1874, the work of laying the dimension stone began, and progressed, whenever the weather allowed, during the autumn, though only some 1,100 cubic yards were laid before the inclemency of the weather caused a suspension for the winter.

In the beginning of this work it was attempted to use stone of tapering widths in the stretcher courses, which was not objected to if other stone were selected or shaped to conform roughly to their shape when laid alongside of them. But as the water was rarely clear enough for any length of time to allow the divers to see objects over two feet from their eyes, this adaptation of one stone in hand to another already laid was found to be impracticable, without greater cost than to prepare them with parallel sides. This method was, therefore, pursued by the contractor after awhile, except for the courses consisting entirely of headers,

which were got out in pairs or single stones, and could more readily be laid heads to points than the courses consisting entirely of stretchers. In order to ensure proper bearings, it was found necessary to gauge the thickness of every stone before lowering it into the water.

The attainment of "one inch joints," and "good bearings without pinners," required by the specification, occasioned much trouble and constant vigilance on the part of the inspector, as well as greater cost in fitting on the part of the contractors than they had anticipated. It occurred here, as in other places where stone are laid in uniform courses, that bunches were often found on the top of a course already laid, arising from slight excess of thickness or a slightly winding surface. Such bunches are readily detected, and readily pointed down after laying, when laying stone above water, but not so in submarine work. If allowed to remain, the next stone above, which may be ten feet long, is tilted up an inch at the end by a bunch of half an inch under its middle, and the error goes on increasing as we go up, for the difficulty of finding such places in muddy water prevents selecting thinner stone to lie over them. The inevitable result would be the breaking of all long stones. Even when the bearings are good for the whole length of a stone, the slack places in its bed, coming over similar slack places of half an inch depth in the build of the lower stone, will make plenty of joints a full inch open, so it becomes very necessary to look out for the winding stones and those having bunches, however small beyond the planes of bearing, *before* they are lowered into the water, for it is too costly to bring them up for refitting.

The completion of this work occupied the whole of the years 1875 and 1876. It is now a year since it was loaded by the filling, and its stability has been quite satisfactory. The actual settlement of its lower course along its whole length, and its progress in detail, is given in the tables B and C, together with the present level of the top of coping above mean low water. The settling of the granite wall has taken place with such uniformity that scarce any cracks have been formed in the cemented joints of the coping. The largest crack had opened about one-fourth of an inch over a year ago at the top. It was repointed in 1876, and subsequently opened one-eighth of an inch. It has been again pointed in 1877, and now shows nearly one-sixteenth of an inch opening. The total motion is therefore less than half an inch, and appears to be decreasing. No forward or lateral movement has been detected in this wall, except the very slight one indicated by this crack. Not a stone has been broken by this movement.

This wall, as now built, is certainly capable of resisting a much greater thrust, without sliding forward on its bed, than if the dimension-stone had been laid directly on the clay, for its base is composed of large angular stones, imbedded in the clay by the superincumbent load, while it covers by its base more than double the width of a wall built as at first proposed, entirely of block-stone from the bottom. In constructing it, the broken stone, as above described, were mostly deposited in 1874, and were allowed to remain till the following year before proceeding with the dimension-stone above. In fact, only 1,200 cubic yards of the latter were laid prior to April, 1875. The unequal settlement of the broken stone actually taking place on the different qualities of material, really caused no practical inconvenience, for this work was levelled up after such unequal settlement had nearly reached its limits.

Heavy Wall East of the Dock.

In providing for the strip of heavy wall along the harbor-line east of the dock on the flats belonging to the State, and between this and the dock on the flats of the Boston & Albany Railroad Company, the same reasons did not appear to exist for the base of broken stone twelve feet high which had existed on the portion described above, west of the dock. Between the two docks the foundation was quite uniform in texture, giving less reason than further west for unequal settlement, while the conditions of the back filling were such as to impose a lighter load per linear foot of the whole work, for this filling was only to extend against the central portion of its length, 156 feet only being filled out of a total length of about 180 feet, the dock walls being connected with it about 32 feet back from its ends. Still another reason appeared for adhering to the principal features of the original plan at this place, viz., the greater exposure here existing to the erosive effect of waves on the bottom, which might perhaps disturb a foundation of broken stones having a steep slope. It was therefore determined to adhere to a modification of the original plan for this part of the heavy wall which was built as indicated on Plan XII, the modification referred to being this. The foundation was dredged about four feet below the base of the wall, and the trench filled with small broken stones to diminish the risk of slipping. Previous, however, to advising this style of wall at this place, the bottom was thoroughly tested. A description of these experiments may be of interest.*

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* The writer is indebted to Mr. Jos. P. Frizzell for conducting these experiments, with Mr. J. O. Osgood, inspector.

The dredging having been completed along the whole length of the proposed pier-head to the required depth of 23 feet below low water, piles were driven at intervals, in order to learn what degree of uniformity existed in the general character of the bottom. The dredging and pile-driving both tended to show a great uniformity in the physical characteristics of the bottom along the whole length of the work. It was a firm though fine clay, soft enough to allow of piles being driven into it with ease. Selecting a central point for the experiment, a group of piles was driven into it and fastened together at the top, where a small platform was built on them. A single pile, with squarely-sawed point, was set upright, resting its point on the clay, while its top was held vertically over its lower end by the platform, through a hole in which it was allowed to slide. A small cross-head was then made fast to the top of this loose pile, on which definite weights were applied, while the amount of settlement under these weights was observed by a levelling instrument, and referred to a fixed bench-mark.

The results were as follows :

The figures under the head of "settlement" indicate the new or additional subsidence due to the increase of load.

Total weight in pounds applied.	Pounds per square foot of bearing surface.	Settlement in feet.	Interval during which settlement occurred before it was measured.
670	2,921	0.03	17 hours.
1,300	5,668	0.06	7½ hours.
2,500	10,900	0.04	At once.
2,500	10,900	0.05*	16 hours.
2,830	16,700	0.04	At once.
2,830	16,700	0.20*	7 hours.
2,830	16,700	0.25*	21 hours more.
2,830	16,700	0.00*	72 hours more.
2,830	16,700	0.03*	72 hours more.
2,830	16,700	0.025*	¼ hour more.

This material can be compared to that existing in other places by comparing the amount of resistance offered by each material to the penetration of square-pointed piles under the hammer ; and for the sake of such a comparison, a statement is given below of the successive penetration of several piles here driven. The hammer weighed 1,385 pounds. The piles were selected of about the same size, viz., 6½ inches diameter at the point ; they varied from 43 to 53 feet in length. The water was about deep enough to float the piles as they stood upright before being driven, so their own weight counted for nothing.

* Additional.

		Blow.	Fall of hammer.	Penetration.
Platform piles.	First pile	1st.	8 ft.	$7\frac{1}{2}$ inches.
	"	2d.	8 ft. $7\frac{1}{2}$ in,	6 "
	"	3d.	9 ft. $1\frac{1}{2}$ in.	$5\frac{1}{2}$ "
	Second pile	1st.	7 ft. 2 in.	8 "
	"	2d.	7 ft. 10 in.	6 "
	"	3d.	8 ft. 4 in.	$7\frac{1}{2}$ "
	Third pile	1st.	7 ft. 6 in.	$6\frac{3}{4}$ "
	"	2d.	8 ft. $\frac{3}{4}$ in.	$7\frac{1}{4}$ "
	"	3d.	8 ft. 8 in.	$7\frac{1}{2}$ "
	Fourth pile	1st.	6 ft.	7 "
	"	2d.	6 ft. 7 in.	7 "
	"	3d.	7 ft. 2 in.	$9\frac{1}{2}$ "
	Fifth pile	1st.	6 ft. 6 in.	$7\frac{1}{4}$ "
	"	2d.	7 ft. $1\frac{1}{4}$ in.	7 "
	"	3d.	7 ft. $8\frac{1}{4}$ in.	$8\frac{3}{4}$ "
	Sixth pile	1st.	7 ft. $7\frac{1}{2}$ in.	$8\frac{7}{8}$ "
	"	2d.	8 ft. $4\frac{3}{8}$ in.	$11\frac{1}{8}$ "
	"	3d.	9 ft. $3\frac{1}{2}$ in.	$11\frac{3}{4}$ "
	Seventh pile	1st.	8 ft.	$18\frac{1}{2}$* "
	"	2d.	9 ft. $6\frac{1}{2}$ in.	$9\frac{1}{2}$ "
	"	3d.	10 ft. 4 in.	$9\frac{1}{2}$ "

The next step was to determine what amount of friction this clay would afford as a resistance to the sliding outward of the wall on its base, where it has no foothold, standing on a level with the harbor floor.

For this purpose, a rough block of granite was dragged over a level bed of clay, immersed in the water, while the amount of force needed to produce sliding was measured with a spring balance. A mean of some 42 trials gave for the coefficient of friction at starting, 0.328, and after starting, 0.224, while in motion. In practice this can be largely increased by depositing broken stone on the bottom.

The actual condition here existing, affecting the stability of this work, may be described as follows : The wall is, except for a short distance at each end, to act as a retaining wall for the solid filling behind it, while the ebb and flow of the tides bring a mass of water in its front, varying some 12 feet in height—being from 22 to 34 feet in depth at spring tides. Since the lower 12 courses are laid without cement, the water passes freely through the wall, rising and falling with every tide among the material in its rear, as far as such material is not impervious to it. A porous ballast is placed immediately behind the wall, but beyond this the material, for 36 feet in height above its base, is a slippery clay, reduced by handling to a semi-fluid condition when first deposited, and

* Mud.

acquiring gradually a more solid character by the expulsion of water from among its particles, through their greater specific gravity, which was about double that of sea water. This is a slow process; the well-known characteristic of the material being a tendency to resist the percolation of water through its mass; so that many months elapse after its deposit before it becomes as compact as when first found in the harbor. In this latter condition we are obliged to use it as a foundation to build on. It had been found by actual experiment that this material would bear a load of some 5 000 pounds per square foot without flowing out perceptibly from under this load; also that an increase of load above this point was soon accompanied by a tendency to flow, which was apparently continuous for a number of days, when a load of 16 000 pounds per foot was applied. The quantity of clay to be moved by flow from under such a load would increase materially with the settlement of the load, for the first few inches of the displacement, by the accumulation of this displaced material, after which a channel might be established for its escape. A point of equilibrium seemed to be reached in our experiments, where a slight settlement taking place at first, was checked by this increase of resistance until by successive applications of new loads, a load of about 16 000 pounds per foot was reached, when this settlement seemed to become continuous during the experiment. It was, therefore, considered desirable to limit the maximum load to 5 000 pounds per foot, if possible, although a heavier load might not produce much trouble, within the limits of 7 000 or 8 000 pounds per square foot.

The amount and direction of the pressure exerted upon such a wall by the earth behind it, depend upon these two data: (*A*) The specific gravity of the material; (*B*) the natural slope of the material, when a bank of it is left to assume its own slope. This angle is the natural resultant of the friction of the particles as exerted to prevent sliding, and the gravity of the mass. It is, therefore, sometimes called the angle of friction, and its tangent is the coefficient of friction of the material.

Since the investigations of Prony, in the early part of this century, it has been accepted as proved, that the maximum pressure of earth in such cases is exerted, not by the whole prism lying between its natural slope and the back of the wall, for the tendency to slide in that prism is just balanced by friction, and it would not tend to move at all; but this maximum pressure is exerted by the prism contained between the back of the wall and a plane inclined upward from its base, so as to bisect the angle between the vertical and the natural slope. The sliding of this

prism downward would, therefore, throw the centre of pressure in the direction of this limiting plane on which the sliding takes place, *i. e.*, parallel to it; and as the centre of gravity in such a prism, if homogeneous, would be at two-thirds the distance from the top of the wall to the centre of this sloping plane, the line of pressure would strike the back of the wall at a point one-third way up from the base. The value of the horizontal thrust on the wall at this point is expressed by the following formula:

$$P = \frac{Wh^2}{2} \text{ tangent}^2 \tfrac{1}{2} (90^\circ - \varphi)$$

Where P = horizontal pressure on wall for a unit of length.

W = weight of a cubic unit of filling material.

h = height of wall.

φ = angle of repose of filling material, counting from the horizon.

In other words, this pressure for a unit of length of wall equals the product of the weight of the prism for a unit of length by the tangent of one-half the complement of the angle of repose; for the weight of such a prism is—

$$= \frac{W}{2}, h^2 \text{ tangent } \tfrac{1}{2} (90^\circ - \varphi)$$

Of these elements the weight of the filling is easily obtained, and is found by experiment to be about 125 pounds per cubic foot. The height of the wall is 39 feet. It only remains to find the angle of repose of the material. It is upon this point that all the uncertainty arises which enters into such calculations, and renders them often of little value. The natural slope of earth, when not subject to the wash of water, is generally taken at about 33° 18′. But the clay with which we have to deal possesses, when first deposited, almost the fluidity of mortar, and its natural slope is found to be as low as 3°, till time is given for it to expel the water with which it has been mixed. It follows that a wall of enormous height and breadth of base would be required to hold up such a filling for the period of its transition from a semifluid to a comparatively solid state; so that much economy would result by using plenty of time in so disposing this back filling as to increase the angle of repose as far as possible. The first step in this direction is to place in immediate contact with the rear of the wall a quantity of porous material or ballast, which will not only drain the filling in the immediate neighborhood, but serve to increase the angle of the natural slope. Such material was provided for this purpose in the specifications; viz.: porous gravel,

stones, or oyster-shells. The gravel would have a natural slope of some 33° 18′, and the stones or shells, if used, a slope of 40°. But the prism of greatest pressure would not be composed entirely of such ballast. There would be a considerable amount of clay, and this would tend to make the whole mass slide at a flatter slope than the ballast alone would assume. The natural slope of the combination would be somewhere between that of the two substances considered separately. A large number of experiments made upon the friction of this clay, led us to suppose that its angle of repose, when not mixed with water, was more dependent on its cohesion than friction; and a disposition to flow under extreme pressure was generally developed, even when at its hardest state. If we could rely upon the complete expulsion of the water from its mass before completing the loading of the wall, and if we chose to rely on cohesion, we might rely on a natural slope of some 35° perhaps for that of the ballast and clay together. But the difficulty of attaining this result, and the uncertain character of the element of cohesion, indicate that prudence would require the assumed angle to be less than that of common earth alone; say as small as two of base to one of height, or 26° 34′ for the condition of things soon after loading the wall. In order to indicate the direction and value of the resultant pressure on this supposition, the annexed diagram is made. See plate XIII.

In this diagram the section of the wall is shown by the figure *ABD*. The supposed natural slope of the material behind it, when partially consolidated, is shown by the line *BF*, with an angle of 63° 26′ from the vertical. The prism of maximum pressure would then be included between the lines *BA* and *BE*. It would tend to slide down the line *BE*, and, if composed of homogeneous materials, would give a line of pressure parallel to this side, and intersect the wall at one-third its height above its base. But we have here conditions somewhat different from these. The water passes freely through the wall and the ballast, so that the centre of gravity of the prism *A B E* would not be at the centre of gravity of this triangle. Extreme low water is evidently the time when the greatest earth pressure exists. But the material below the water at any time would not count at its full weight, but at a weight depending on its excess of specific gravity over that of sea water. On computing the centre of gravity of the figure upon this basis we find it at the point *C′*. and drawing thence the line *C′H* parallel with *BE*, we find the line of pressure intersects the back of the wall at a point *H*, more than a foot above the lower third of the height of the wall. The weight of such a

prism one foot long, allowing for the buoyancy of the water, is computed at 50,028 pounds, as indicated under the point C', The horizontal pressure on the wall is then found by the formula above quoted.

$$P = w' \text{ tangent } \tfrac{1}{2}\,(90^\circ - \Phi).$$

w' being the weight of the mass, $ABE = 50{,}028$.

Φ being $26^\circ\ 34'$ and $\frac{1}{2}\,(90^\circ - \Phi)$ being $31^\circ\ 43'$ from which we have $P = 30{,}920$ lbs.

We want now to combine this horizontal force with the weight of the wall. This is supposed to act from its centre of gravity, C, with a vertical force of 53,490 pounds ; the portion below low water being diminished in weight by the buoyancy of the water, and the centre of gravity being higher than that of the figure. The resultant is found by computing the diagonal of the force parallelogram to be in a direction shown by the line IJK, making an angle of $30^\circ\ 02'$ with the vertical. and having a value of 61,790 pounds. This would intersect the base at K, distant 3.85 feet from the outer corner of the wall, and would indicate a degree of instability from the following reasons : The angle $30^\circ\ 02'$ is somewhat greater than the angle of friction between stone and stone, as generally accepted, and decidedly greater than that between stone and clay. This might lead to the sliding forward of the wall. Moreover, the pressure on the base is not uniform, but has a maximum at the point D of some 8,500 pounds per square foot, even supposing the horizontal component of this resultant to be cancelled by friction. It had been found by our experiments above referred to, that a pressure of this amount on the clay bed under the wall began to produce symptoms of flow from under the load, hardly consistent with stability.

But we have thus far neglected the items of water pressure and friction between the filling and the back of the wall. Since a very slight rolling motion in the wall might take place about the point B, without producing friction on the line $B\ A$, it was not thought prudent to rely on this ; although Mosely and some other writers suggest such a reliance. But the water pressure certainly does act to some purpose in assisting stability. For although it flows freely through the wall and the ballast, it meets, sooner or later, an impervious material against which it stops and exerts the known pressure, and a part of this may doubtless be reckoned upon to hold back and cancel, *pro tanto*, the earth pressure. A line is drawn on the diagram showing the water-pressure at extreme low water, intersecting the front of the wall and normal to it, at a point one-third the height from the bottom to top of the water, having a value of

14,112 pounds. If the wall were a tight diaphragm, this would produce the resultant *JL*, when combined with the above described forces. In reality, this resultant may be considered to lie between the lines *KJ* and *JL*. The latter has an angle of 73° 10′ with the horizontal; or 16° 50′ with the vertical, which is evidently within the limits of stability.

The result of the above investigation indicates that it is desirable to keep the material behind the wall in such a condition that the angle of repose would always be slightly greater than here shown, which is a condition verging on the extreme limits of stability. This end can generally be attained by giving attention to the manner in which the filling is deposited; viz., to insure its being deposited in successive layers, giving time for the consolidation of each layer by the expulsion of water from among its particles before applying the next one, and giving each successive layer a slope *from* the wall, by keeping the material highest next the wall. These well-known rules in the application of filling behind a retaining wall are particularly important when using a material like this clay, which acts more like a fluid than a granular substance, and is always inclined to flow under pressure, even when consolidated as far as possible, the only condition being that the pressure shall overcome its cohesion, a power of resistance difficult to determine, and which all prudent engineers hesitate to rely upon.

The above investigation also indicates the apparent lack of stability in case the wall were to be founded directly upon the clay, as at first proposed in 1869, for the friction of granite blocks upon the clay is far inferior to that of the same blocks upon the broken stone, while the latter, being imbedded or indented into the clay at the bottom of the trench, get a far better hold than flat stones would do, resting on a flat clay bottom.

The foundation for the 180 feet of heavy wall between the docks was prepared in the year 1876, as above described, by dredging three or four feet below its base, and levelling up with small broken stones from one to four inches diameter, carefully packed and levelled with a straight-edge. During the year 1876, about seven courses of dimension-stone were laid upon this by divers, each course being alternately all headers and all stretchers up to low water. Each stone was gauged by an inspector before being lowered into the water; and when, in the spring of 1877, the work appeared for the first time above water, there was not over an inch variation in its level throughout its whole length. It has since been finished in cement masonry up to grade 16, the dock walls having been

bonded into it as it was laid. The filling has but recently been applied, but, as the pressure of such filling against the wall is more severe immediately after its application than ever likely to be afterward, its present stability is an apparent guarantee for that of the future. A record of its settlement is appended in Table D.

In the tabular statements appended (tables E, F and G), will be found a record of the payments made under the contracts with Messrs. Clapp & Ballou, also a statement of the quantities of each kind of work done, with the nominal prices attached, by which partial payments have been made during the progress of the work, amounting, when finished, to the contract prices per lineal foot of wall, and square foot of filling.

Testing of Cement used in the Heavy Walls above Low Water.

As this cement was often covered by tide water almost immediately after being applied, and always within 10 or 12 hours, until above high water, it was desirable to use an article possessing the quality of setting quickly, as well as of a uniform quality in other respects, such as fineness, &c. Samples were drawn from each barrel. These were mixed with a definite and minimum quantity of water, and moulded for attachment to the testing apparatus. These samples were then immersed in water for 24 hours and afterwards broken by tension in an apparatus made for the purpose, weighing the force applied on a scale beam. Another apparatus was made to test the resistance to crushing, but this test was not found to be so useful in practice as the former. All barrels were rejected which did not yield a tensile strength of sixty pounds per square inch of section after the twenty-four hours in water. A detailed statement of the results of testing large quantities of cement offered is appended hereto (see Tables H and I), showing the gain in strength by lapse of time while immersed in water for various periods up to two years, also comparison of results for various proportions of sand and for salt and for fresh water for making the mortar.

The pointing of the face joints of this wall was originally of good American cement, applied under the contract, but it was found to have been considerably loosened by the frost during the two past winters between high and low water, and arrangements were therefore made in 1877 to replace this pointing with Portland cement, where not perfectly sound. This was applied without sand, and promises to be more durable in this trying position.

Filling Behind the Walls.

The material for filling was the clay dredged from the harbor, with the exception of the ballast behind the walls and for the upper three feet next the surface. This clay was generally so stiff as to require the use of a heavy scoop dredge, and was brought around the walls in scows and dumped about the time of high water, until the filling had accumulated up to about half tide, after which loaded scows could not be floated. The remainder of the clay was dumped in piles in front of the walls and lifted over them with a clam-shell dredge, which swung its arm around over the wall and dropped the clay into small tramway cars, handled by a light locomotive. The tramways extended over the partially filled flats, supported on pile trestles. The car bodies were not on rockers like gravel cars, but had side boards hinged at the top, with bottoms sloping down on each side from the centre, so that when the side boards were raised the clay slipped out on both sides. The repeated handling had reduced the material to the consistency of mortar, so that it spread for several hundred feet on either side of the tram, and avoided the construction of many lines of trestles.* The ridges left alongside the tramway were removed by wheel-barrows into the hollows. This material as thus dumped weighed about 125 lbs. per cubic foot, and as it was of a semi-fluid consistency, capable of exerting an enormous horizontal pressure, great care was needed in depositing it near the walls to avoid crowding them over or pushing them bodily forward. The method generally adopted was to drop this material over the wall directly on to the ballast, until some four or five feet in depth had accumulated, then to move along and wait several weeks for this first deposit to consolidate by expelling the water from its particles before putting on another layer. After the clay had been accumulated by thus dropping it over the wall to a height near the top of the wall, it sloped back for some hundred feet or more over the material previously dumped from scows, and the dumping from the tramways in the interior of the field finished the clay filling.

The gravel for the ballast behind the walls and part of that used for the surface was brought by scows from dredgings around the Great Brewster Spit, near the mouth of the harbor, and was dumped, hoisted over the wall, and distributed in the same manner as the clay. But the

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* It was found in practice that lines of trestles some two hundred feet apart would fill the intervening spaces with but little wheeling of material to level up.

larger portion of the surface gravel was brought in from Readville by rail, about nine miles, on the line of the New York & New England Railway.

Dredging Done.

While getting material for filling the area behind the above described walls, the following dredging has been done:

Fort Point Channel has been dredged on a slope longitudinally beginning with 12 feet, reaching a depth of 23 feet at low water, at a point about midway the length of the heavy wall west of the dock. The portion of this channel opposite the light wall is 400 feet wide. Passing eastward the width gradually contracts to about 200 feet before arriving at the first dock. Near the entrance to this dock, it is widened again to a width of 400 feet, with a depth of 23 feet at low water. This width allows vessels to turn in entering or leaving the dock. From this point, a channel is dredged about 200 feet wide and 23 feet deep at low water nearly due east to the main ship channel. A considerable amount of material has also been taken from a shoal off the end of Long Wharf.

The dock on the Commonwealth's flats has a depth of 23 feet at low water through its whole length, up to within 50 feet of the walls on each side, which is as near the walls as it will be safe to dredge, before the platforms are built, owing to the difficulty in controlling the dredging machines with any exactness. This bank of clay on each side will be a sufficient protection to the walls until the platforms are built, after which it may or may not be found necessary to dredge a small quantity along their front lines.

Inspection.

The difficulty of inspecting submarine masonry is often felt to be a serious drawback upon its use. The difficulty in most cases arises in part from the lack of intelligence and habits of accurate observation on the part of the men employed as divers, and in part from the possible want of independent judgment, veracity, and integrity in men who either have been, are now, or expect to be in the future, dependent for employment upon the contractors whose work they are to examine and report upon. Perfect independence is a *sine qua non* for a good inspector, however good his other qualifications may be. In the work above described the State was fortunate in securing the services of the assistant engineer in charge to inspect all the submarine work in person. This was done in ordinary diver's armor, and without any injurious effects except temporary discomfort at times.

TABLE A.

Levels on the Fort Point Channel and Dock Walls.—Showing Settlement.

(Referred to Mean Low Water.)

Fort Point Channel Wall. Distances from commencement of curve of 910 feet radius.	Elevation. 1874.	Elevation. 1877. December 8.	Dock Wall. Lettered stations are about 50 feet apart.	Elevation. 1876.	Elevation. 1877. December 8 and 10.	Dock Wall. Lettered stations are about 50 feet apart.	Elevation. 1876.	Elevation. 1877. December 10.
End of Wall.			West Side.			East Side.		
314½ feet S. of P. C.	16.00	15.62	Y,	16.00	15.89	S. E. corner, I — 7	16.00	15.91
300 " "	16.00	15.79	X + 25	16.00	15.86	I,	16.00	15.90
275 " "	16 00	15.73	X,	16.00	15.84	+ 25	16.00	15.92
250 " "	16.00	15.65	W + 25	16.00	15.91	J,	16.00	15.87
225 " "	16.00	15.70	W,	16.00	15.87	+ 25	16.00	15.80
200 " "	16.00	15.56	V + 25	16.00	15.96	K,	16.00	15.86
175 " "	16.00	15.48	V	16.00	15.94	+ 25	16.00	15.71
150 " "	16.00	15.66	U + 25	16.00	15.81	L,	16.00	15.92
125 " "	16.00	15.66	U,	16.00	15.69	+ 25	16.00	15.87
100 " "	16.00	15.73	T + 25	16.00	15.74	M,	16.00	15.85
75 " "	16.00	15.78	T,	16.00	15.77	+ 25	16 00	15.83
50 " "	16.00	15.93	S + 25	16.00	15 84	N,	16.00	15.88
25 " "	16.00	16.06	S,	16.00	15.83	+ 25	16.00	15.96
0 " "	16.00	15.94	R + 25	16.00	15.83	O,	16.00	15.86
25 " N. of P. C.	16.00	15.66	R,	16.00	15.93	+ 25	16.00	15.90
50 " "	16.00	15.82	Q + 25	16.00	15.77	P,	16.00	15.85
75 " "	16 00	15.86	Q,	16.00	15.83	+ 25	16.00	15.92
100 " "	16.00	15.99	P + 25	16.00	15.79	Q,	16.00	15.88
125 " "	16.00	15.98	P,	16.00	15.76	+ 25	16.00	16.00
150 " "	16.00	16.09	O + 25	16.00	15.70	R,	16.00	15.98
175 " "	16.00	16.02	O,	16.00	15.74	+ 25	16.00	15.94

200 feet N. of P. C.	16.00	15.81
225 " "	16.00	15.94
250 " "	16.00	15.91
275 " "	16.00	15.90
300 " "	16.00	15.71
325 " "	16.00	15.71
350 " "	16.00	15.80
375 " "	16.00	15.80
Corner	16.00	15.84
Middle of Spur to Heavy Wall	16.00	15.88
	16.00	15.81
	15.81	
Average settlement, =	0.19	

N + 25	16.00	15.76
N,	16.00	15.80
M + 25	16.00	15.86
M,	16.00	15.70
L + 25	16.00	15.83
L,	16.00	15.81
K + 25	16.00	15.79
K,	16.00	15.69
J + 25	16.00	15.78
J,	16.00	15.83
I + 25	16.00	15.76
I,	16.00	15.71
S.W.cor. 1 — 7	16.00	15.63
	16.00	15.80
	15.80	
Average settlement, =	0.20	
END.		
25 feet from S.W. corner	16.00	15.62
50 " "	16.00	15.95
75 " "	16.00	15.81
100 " "	16.00	15.84
125 " "	16.00	15.81
150 " "	16.00	15.88
	16.00	15.82
	15.82	
Average settlement	0.18	

S,	16.00	15.92
+ 25	16.00	15.94
T,	16.00	15.91
+ 25	16.00	15.82
U,	16.00	15.69
+ 25	16.00	15.86
V,	16.00	15.89
+ 25	16.00	15.94
W,	16.00	15.79
+ 25	16.00	15.95
X,	16.00	15.84
+ 25	16.00	16.00
Y,	16.00	15.79
+ 25	16.00	15.92
Corner, junction with heavy wall	16.00	16.06
	16.00	15.89
	15.89	
Average settlement, =	0.11	
Mean of levels on the whole dock	.....	15.84
	16.00	
	15.84	
Average settlement on whole dock	0.16	

TABLE B.

LEVELS ON HEAVY WALL, WEST OF DOCK. SHOWING AMOUNT OF SETTLEMENT. THE ORIGINAL LEVEL OF COPING WAS 16.00.

[Referred to Mean Low Water.]

Lettered stations are 17.61 feet apart; Dolphins, 105.64 feet apart.		Elevation of top of Bottom Course.										Height of Wall above Bottom Course. (Bottom C = 2 feet.)	Elevation of Top of Wall (front line of caps) Dec. 8, 1877.
		Oct. 7, to Nov. 16, 1874.	Nov. 28, to Dec. 2, 1874.	April 1 and 2, 1875.	May 6, 1875.	May 21, 1875.	July 8 and 9, 1875.	Aug. 27, 1875.	Oct. 12, 1876.	Oct. 15, 1877.	Dec. 8, 1877.		
West end of wall	A	— 9.24	..	— 9.24	..	..	..	..	— 9.87	— 9.91	— 9.94	25 57	15.63
Dolphin No. 4, 29 feet from west end of caps	B	— 8.98	— 8.98	— 8.99	..	..	— 9.18	..	— 9.76	— 9.80	— 9.81	25.41	15.60
	C	— 9.03	— 9.02	— 9.06	..	..	— 9.18	..	— 9 87	— 9 92	— 9.96	25.53	15.57
	D	— 9.11	— 9.12	— 9.11	..	.	— 9.20	..	— 9.89	— 9.93	— 9.96	25.47	15.51
	E	— 9.13	— 9.13	— 9.14	..	..	— 9.25	..	—10.06	—10.09	—10.11	25.58	15.47
	F	— 9 11	— 9.12	— 9.11	..	..	— 9.27	..	—10.10	—10.15	—10.18	25.58	15.40
	G	— 9.03	— 9.03	— 9.03	..	..	— 9.16	..	—10.00	—10.03	—10.06	25.46	15.40
	H	— 8.97	— 8.97	— 8.99	..	..	— 9.08	..	— 9.88	— 9.90	— 9.93	25.40	15.47
Dolphin No. 5	I	— 8.81	— 8.82	— 8.84	..	..	— 8.94	..	— 9.73	— 9.75	— 9.77	25.27	15.50
	J	— 9.03	— 9.03	— 9.05	..	..	— 9.12	..	— 9.89	— 9.92	— 9.95	25.45	15.50
	K	— 8.95	— 8.94	— 8.95	..	..	— 9.06	..	— 9.82	— 9.85	— 9.89	25.35	15.46
	L	— 8.96	— 8.97	— 8.98	..	..	— 9.08	..	— 9.79	— 9.82	— 9.87	25.38	15.51
	M	— 8.92	— 8.92	— 8.92	.	..	— 9.10	..	— 9.73	— 9.78	— 9.85	25.31	15.46
	N	— 9.02	— 9.03	— 9.02	..	..	— 9.16	..	— 9.81	— 9.88	— 9.95	25.38	15.43
Dolphin No. 6	O	— 9.03	— 9.05	— 9.03	..	..	— 9.12	..	— 9.81	— 9.84	— 9.90	25.36	15.46
	P	— 8.95	— 8.99	— 8.97	..	..	— 9.10	..	— 9.75	— 9.78	— 9.84	25.35	15.51
	Q	— 8.96	— 9.00	— 8.98	..	.	— 9.08	..	— 9.70	— 9.73	— 9.77	25.29	15.52
	R	— 9.03	— 9.04	— 9.05	..	..	— 9.11	..	— 9.74	— 9.76	— 9.80	25.33	15.53
	S	— 8.97	— 8.98	— 9.00	..	..	— 9.09	..	— 9.73	— 9.75	— 9.77	25.36	15.59
	T	— 8.93	— 8.94	— 8.96	..	..	— 9.10	..	— 9.80	— 9.81	— 9.84	25.39	15.55

Dolphin No. 7	U	— 8.90	— 8.91	— 8.94	— 8.94	..	— 9.06	— 9.05	— 9.76	— 9.78	— 9.80	25.38	15.58
	V	..	— 8.97	— 9.00	— 9.00	..	— 9.08	— 9.10	— 9.74	— 9.76	— 9.79	25.39	15.60
	W	..	— 9.02	— 9.06	— 9.09	..	— 9.14	— 9.17	— 9.84	— 9.88	— 9.90	25.51	15.61
	X	..	— 8.91	— 8.95	— 8.95	..	..	— 9.07	— 9.69	— 9.73	— 9.74	25.36	15.62
	Y	..	— 8.88	— 8.93	— 8.93	..	..	— 9.05	— 9.69	— 9.73	— 9.76	25.42	15.66
	Z	..	..	— 9.02	— 9.02	— 8.92	..	— 9.13	— 9.63	— 9.65	— 9.68	25.32	15.64
Dolphin No. 8	A′	..	— 8.93	— 8.97	— 8.97	— 9.04	..	— 9.05	— 9.65	— 9.67	— 9.70	25.41	15.71
	B′	..	..	..	..	— 8.98	..	— 9.04	— 9.61	— 9.64	— 9.66	25.44	15.78
	C′	..	..	..	..	— 8.99	..	— 9.02	— 9.53	— 9.57	— 9.59	25.32	15.73
	D′	..	..	..	..	— 8.98	..	— 9.22	— 9.52	— 9.57	— 9.60	25.33	15.73
	E′	..	..	..	..	— 9.18	..	— 8.94	— 9.40	— 9.46	— 9.49	25.27	15.78
	F′	..	..	..	..	— 8.94	..	— 8.95	— 9.45	— 9.56	— 9.60	25.36	15.76
Dolphin No. 9	G′	..	..	..	..	— 8.98	..	— 9.03	— 9.48	— 9.55	— 9.58	25.36	15.78
	H′	..	..	..	..	— 9.03	..	— 9.07	— 9.48	— 9.57	— 9.59	25.36	15.77
	I′	..	..	..	..	— 9.06	..	— 9.15	— 9.41	— 9.51	— 9.55	25.32	15.77
	J′	..	..	..	..	— 9.12	..	— 9.16	— 9.60	— 9.70	— 9.74	25.46	15.72
	K′	..	..	..	..	— 9.06	— 9.10	— 9.10	— 9.57	— 9.70	— 9.74	25.39	15.65
	L′	..	..	..	..	— 9.04	— 9.10	— 9.09	— 9.54	— 9.68	— 9.72	25.36	15.64
Dolphin No. 10	M′	..	..	..	..	— 9.07	— 9.12	— 9.12	— 9.52	— 9.69	— 9.74	25.39	15.65
	N′	..	..	..	..	— 9.04	— 9.09	— 9.06	— 9.49	— 9.66	— 9.70	25.35	15.65
	O′	..	..	..	..	— 9.08	— 9.10	— 9.10	— 9.54	— 9.71	— 9.75	25.48	15.73
	P′	..	..	..	..	..	— 9.08	— 9.04	— 9.43	— 9.59	— 9.62	25.36	15.74
	Q′	..	..	..	..	..	— 9.14	— 9.10	— 9.45	— 9.61	— 9.64	25.39	15.75
	R′	..	..	..	..	..	— 9.14	— 9.17	— 9.50	— 9.64	— 9.68	25.43	15.75
Dolphin No. 11	S′	..	..	..	..	..	— 9.05	— 9.05	— 9.47	— 9.58	— 9.61	25.38	15.77
	T′	..	..	..	..	..	— 9.05	— 9.15	— 9.46	— 9.54	— 9.55	25.36	15.81
East end of wall	U′	..	..	..	..	..	— 9.08	— 9.20	— 9.49	— 9.54	— 9.57	25.42	15.85
Mean of first levels							— 9.02	Mean of last levels			— 9.77	25.39	15.62
											9.02		
								Average settlement			0.75		
								Greatest settlement			1.07		
								Least settlement			0.49		

TABLE C.

Heavy Wall West of Dock.—Approximate Progress of Masonry by Dolphin Ranges.

NUMBER OF COURSE.	West End Begun.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.	No. 9.	No. 10.	East End No. 11. +
1	1874. Aug. 25,	1874. Sept. 1.	1874. Sept. 5,	1874. Oct. 22,	1874. Nov. 7,	1874. Dec. 1,	1874. Dec. 5,	1874. Dec. 29,	1875. June 24,
2	Sept. 5,	Sept. 10,	Oct. 1,	Nov. 2,	Nov. 17,	Dec. 30,	1875. Jan. 9,	1875. April 19,	June 30.
3	1875. April 12,	1875. April 13,	1875. April 22,	1875. May 1,	1875. May 28,	1875. July 9,	Aug 7,	Aug. 13,	Sept. 28,
4	May 5,	May 5,	May 15,	May 26,	June 9,	July 20,	Sept. 2,	Oct. 4,	Oct. 13,
5	June 1,	June 2,	June 18,	July 10,	July 22,	Aug. 18.	Sept. 17,	Oct. 9,	Nov. 5,
6	June 11,	June 14,	June 28,	July 25,	July 28,	Aug. 31,	Sept. 23,	Oct. 15,	Nov. 15,
7	July 3,	July 15,	July 30,	Aug. 15,	Aug. 30,	Sept. 25,	Oct. 5,	Nov. 10,	..
8	July 10,	July 20,	Aug. 15,	Aug. 30,	Sept. 10,	Sept. 30,	Oct. 10,	Nov. 15,	..
9	July 13,	July 23,	Aug. 20,	Sept. 15,	Sept. 25,	Oct. 2,	Oct. 12,	Nov. 20,	..
10	..	July 25,	Aug. 25,	Sept. 19,	Sept. 28,	Oct. 10,	Oct. 25,	1876.	1876.
11	July 29,	Aug. 3,	Aug. 30,	Sept. 22,	Sept. 30,	Oct. 15,	Oct. 28,	1876.	1876.
12	Aug. 10,	Aug. 31,	Sept. 5,	Sept. 25,	Oct. 1,	Oct. 16,	Oct. 29,	1876.	1876.
13	Nov. 11,	..	..	..	..	..	..	1876.	Sept. 7.

TABLE D.

Levels on Heavy Wall East of Dock.—(Referred to Mean Low Water.)

Regular Stations are 20.42 feet apart.		Elevation of Bottom Course. Sept. 26, 1877.	Elevation of Bottom Course. Dec. 20, 1877.	Height of Wall above Bottom Course (Bottom C. = 2 feet).	Elevation of Top of Wall (Front line of Caps), Dec. 20, 1877
End of wall	A,	—20.94	—20.94	37.01	16.07
	B,	—21.04	—21.09	37.11	16.02
	C,	—21.04	—21.07	37.12	16.05
	D,	—21.00	—21.04	37.06	16.02
Dolphin, No. 14, 73.6 ft. from W. end of caps	E,	—20.96	—20.99	37.05	16.06
	F,	—21.00	—21.03	37.11	16.08
	G,	—21.00	—21.02	37.10	16.08
	H,	—21.03	—21.06	37.17	16.11
	I,	—20.95	—20.98	37.10	16.12
Dolphin, No. 15, 105.1 ft. from E. end of caps	J,	—20.94	—20.96	37.13	16.17
End of wall	K,	—20.93	—20.95	37.09	16.14
Mean of latest levels		.....	—21.01	37.09	16.08
Original elevation, top of bottom course		.....	—20.08		
Average settlement		.....	—0.21		
Greatest settlement		.....	—0.29		
Least settlement		.....	—0.14		

N. B.—The datum used for these levels is the same hitherto used in connection with the office of Harbor Commission and Coast Survey. It varies slightly from the datum of the City Engineer's office. This datum can be found by the following bench marks, viz.: North-east corner of door-step of office of Boston Water Board's pipe-yard on Federal street, opposite New York and New England Railroad Station, is called 19.839; coping of Dry Dock in Navy Yard, 14.620.

TABLE E.

Record of Payments made under the Contracts with Messrs. Clapp & Ballou.

WORK DONE.	Lineal Feet. Light Wall.	Lineal Feet. Heavy Wall.	Square feet of Filling.	Total value at the Contract prices.	Reserved under Contract.	Actually Paid.
Before Jan. 1, 1875	641	255.	190,016	$160,139 00	$16,013 88	$144,125 12
Jan. 1, 1876	1,138	743.	349,216	357,682 26	35,768 20	321,914 06
Jan. 1, 1877	2,415	879.	561,692	525,228 21	52,522 82	472,705 39
Jan. 15, 1878	2,635	944.849	884,010 $\frac{6}{10}$	676,313 68	67,631 29	608,682 39

TABLE F.

THE QUANTITIES OF WORK ACTUALLY DONE AT THE VARIOUS POINTS ARE ABOUT AS FOLLOWS, VIZ.;

LOCALITY.	Length on Top.	Tons.	Cubic Yards.
Fort Point Channel wall	$720\frac{49}{100}$	....	$3,187\frac{951}{1000}$
" " broken stone at north end	....	743.	....
Heavy wall west of docks	$802\frac{783}{1000}$	....	....
" " masonry laid by divers	....	....	$3.794\frac{675}{1000}$
" " masonry in cement	....	....	$3,639\frac{437}{1000}$
" " foundations of broken stones.	...	20,500 or	$12,904\frac{887}{1000}$
Heavy wall east of dock	$132\frac{53}{100}$*	....	....
" " masonry by divers	....	....	$1,638\frac{871}{1000}$
" " masonry in cement	....	....	$606\frac{157}{1000}$
" " broken stone in foundation	....	923	....
Dock wall	1861	....	...
" " masonry	....	...	$8,241\frac{576}{1000}$
" " broken stone at north-west corner	....	737	....
" " broken stone at north-east corner	....	1,105	....
" " broken stone under west wall	....	146	....

TABLE G.

Partial payments have been made according to the following list of nominal prices furnished by the contractor, amounting, when multiplied by the estimated quantities of each kind of work, to the contract price per lineal foot of walls: viz.:—

FOR WALL ALONG FORT POINT CHANNEL AND AROUND DOCK:

For piles and planking same, 2 piles per lineal foot, at $5 each	$10 00	per foot.
Digging out and applying ballast between piles	1 50	"
Masonry, $4\frac{2}{3}$ yards per foot, at $3.32 + per yard	15 50	"
Ballasting back of wall, $7\frac{1}{3}$ yards per foot, at $1.50	11 00	"
Guide piles	1 00	"
Total	$39 00	per foot.

FOR HEAVY SEA-WALL WEST OF DOCK.

Broken stone in foundation	$3 00 per yard.		
Levelling the same	50 "		
Guide piles for same	05 "		
15.5 cubic yards per foot length	$3 55 "	$55 025	per foot.
Masonry below low water, 4,691 yards, @ $18		84 438	"
Masonry above low water, 4,531 yards, @ $17.775		80 537	"
Ballast behind wall		16 000	"
Total, as per contract price		$236 000	"

FOR HEAVY WALL BETWEEN THE DOCKS.

Masonry laid by divers, 11.95 yards, @ $15	$179 25	per foot.
Masonry laid above water, 4.531 yards @ $10	45 75	"
Levelling foundation	5 00	"
Ballast behind wall	18 50	"
Total	$248 50	"

* On State's land.

Table H.

Record of Cement Tests.

All from moulds of neat cement mixed with fresh water and broken by tension after immersion for time stated. Temperature of water used in mixing about 60° Fahr't.

Age.	Newark & Rosendale Cement Co. 24-hour tests are from 801 barrels.		Newark, N. J., Lime and Cement Co. 24-hour tests are from 440 barrels.		Newark. N. J., Lime & Cement Co. All tests from 1 barrel.		New York & Rosendale Lime & Cement Co. 24-hour tests are from 180 barrels.		Lawrence Cement Co. "Hoffman Rosendale Cement." Tests from 5 barrels.		Howe's Cave Association. Tests from 4 barrels.	
	No. of tests.	Average strength in lbs. per square inch.	No. of tests.	Average strength in lbs. per square inch.	No. of tests.	Average strength in lbs. per square inch.	No. of tests.	Average strength in lbs. per square inch.	No. of tests.	Average strength in lbs. per square inch.	No. of tests.	Average strength in lbs. per square inch.
16 hours.	54	47	....	....	....	....	....	....	....	....	....	....
24 "	2 217	54.7	1 204	63.1	10	58.	467	45.	6	44.	14	60.
36 "	267	55.3	....	....	....	....	....	....	....	....	....	....
48 "	51	59.6	9	64.	....	....	3	78.5	14	49.5	11	49.
60 "	35	67.6	....	....	....	....	....	....	....	....	....	....
72 "	...	....	....	....	....	....	....	....	....	....	3	77.
4 days.	....	....	....	....	....	....	....	....		72.5	....	....
7 "	28	97.1	....	....	24	71.	1	85.	....	....	...	....
10 "	....	....	....	....	....	....	2	97.5	2	105.	....	....
14 "	12	120.4	....	....	....	....	....	....	....	....	....	....
15 "	....	....	2	133.7	....	....	3	88.	....	..	....	....
19 "	8	139.8	....	.	....	....	....	....	....	....	....	....
21 "	....	....	....	....	....	....	....	....	2	97.	....	....
25 "	....	....	....	....	....	....	....	....	....	....	1	117.
1 month.	....	....	....	....	21	91.8	....	..	7	107.5	....	....
64 days.	....	....	....	....	...	....	1	297.	....	....	....	....
69 "	....	....	....	....	....	....	1	325.	....	....	....	....
2 months.	....	....	....	....	25	157.2	....	....	8	201.5	....	....
3 "	....	....	....	....	....	....	....	....	....	....	1	175.
3¼ "	....	....	....	....	....	....	....	....	2	220.5	....	....
4 "	....	....	....	....	....	....	....	....	....	....	1	177.
6 "	....	....	....	....	....	....	....	....	2	250.	....	....
1 year.	....	....	....	....	....	....	....	....	9	380.6	....	....
1¼ years.	....	....	....	....	29	241.4	....	....	....	....	....	....
2 "	26	257.1	....	....	33	385.1	19	335.5	13	265.8	11	291 7

Table I.

Record of Cement Tests.

From moulds of neat cement mixed with salt water and broken by tension after immersion for time stated.

Temperature of water used in mixing about 60° Fahr't.

Neat Cement.

Age.	Newark, N. J., Lime & Cement Co.		Lawrence Cement Co. "Hoffman Rosendale."	
	No. of tests.	Average strength in lbs. per square inch.	No. of tests.	Average strength in lbs. per square inch.
24 hours.	22	38.9	2	18.7
2 days.	..	....	13	45.
4 "	..	....	2	40.5
7 "	15	56.3	..	....
10 "	..	...	2	49.5
20 "	..	....	3	63.
1 month.	31	105.	3	79.
2 months.	..	....	4	134.
3¼ "	..	....	1	275.
6 "	..	....	4	237.
1 year.	..	....	3	366.7
1¼ years.	29	205.3	..	....
2 "	33	311.	14	233.6

Records of Pile Driving.

The notes on the following pages are from personal observation and measurement, and, together, give a fair statement of the quality of the foundation reached between the Boston Wharf Company's property and the southerly extremity of the heavy wall.

The material is (1) mud, varying in depth from 1 foot to 3 or 4 feet; (2) sand, mud, and clay, in all proportions and so differently mixed that but little can be definitely stated about their arrangement. Frequently muddy sand occurs for 10 feet or more, and is then succeeded by a sandy

yellow clay or by thin seams of quite pure clay alternating with thin seams of sand. Again the mud, sand, and clay, are so intimately mixed that the piles show no difference in penetration other than what is due to the change of fall, &c.

Memorandum of Pile Driving for Foundation of the Light Sea Wall in the State Dock.

Whole number of spruce piles driven in State dock wall foundation under contract of June 23, 1875, 3,645. These by specifications to be 10 inches or more in diameter where sawed off at top.

Books record distances driven for 3,089 of these, aggregating 65,627.5 feet, or an average penetration of 21.25 feet. The least penetration recorded is 14.5 feet. The greatest penetration recorded is 28 feet.

As the trench in which these piles were driven averaged more than 4 feet deep at mean low water, and the penetration when piles were dropped before driving is not included in the above figures, at least 5 feet should be added to the above penetrations to show depths which piles reached below mean low water :

TABLE J.

State Dock.	Depth driven in feet.	Fall of Hammer in feet.	Penetration in inches, last blow.	Number of piles.
Average.....	21.285	26.444	3.768	1861
Piles with max. penetration.	21.	27.	12.	1
Piles with min. penetration.	17 to 22½, av. 19.2	10 to 28, av. 23.9	1.	9
B. & A. Dock, spur.				
Average..... ...	22.054	23.839	5.714	56
Piles with max. penetration.	20.	20.	12.	1
Piles with min. penetration.	22 to 24, av. 23.33	24 to 27, av. 25.33	3.	3

State Dock.	Depth driven in feet	Number of blows.	Penetration in inches, last blow.	Number of piles.
Average.....	20.988	33.482		83
Piles requiring greatest number of blows.....	21.	59.	2 inches, with 27 ft. fall.	1
Piles requiring least number of blows.....	16.	12.	4 inches, with 27 ft. fall.	1

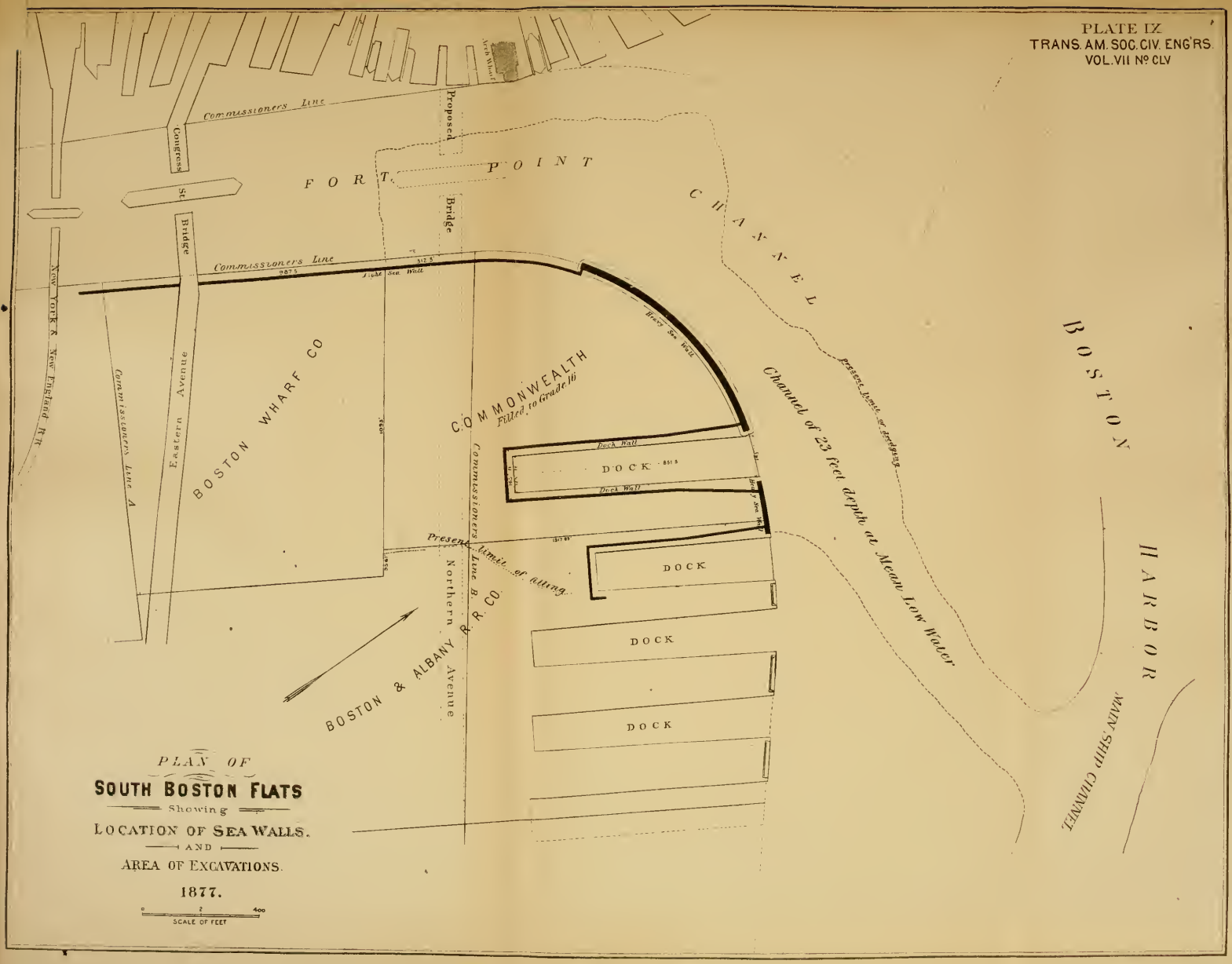
Weight of hammer used, 1,400 pounds.

Memorandum of Pile Driving for Foundation of Light Sea Wall along East Side of Fort Point Channel.

Date.	Whole depth to which piles were driven by hammer.	Last blow.		Hammer used weighed 1,400 pounds.
		Fall in feet.	Penetration in inches.	
Nov. 10th, 1873.	25 feet.	25 feet.	8 inches.	Penetration 6 inches by 18th blow, penetration 2½ inches by 6th blow.
Dec. 24th.	25 ft. or more.	25 "	12 "	Piles 35 feet to 41 feet long.
" 29th.	25 ft. to 30 ft.	25 "	12 " +	Penetration 8 inches with 20 to 25 ft. fall when 20 ft. in ground.
Jan., 1874.	20 ft. to 25 ft.	30 "	6 " +	
"	20 ft. to 25 ft.	30 "	4 in. to 8 in.	
"	18 ft. to 25 ft.	30 "	3 in. to 6 in.	
"	20 feet.	30 "	4 in. to 8 in.	Clay at 15 feet.
"	25 ft. or more	30 ft. to 33 ft.	11 inches.	
"	18 ft. to 30 ft.	30 feet.	6 inches.	These finding clay at 15 feet down.
"	25 ft. to 30 ft.	30 ft. to 33 ft.	8 in. to 14 in.	These finding no stiff material.
"	25 feet.	30 ft. to 35 ft.	6 in. to 12 in.	Driven 8 ft. or more in clay, and moving much less per blow when 3 ft. or 4 ft. in clay than at last blow.
"	25 feet.	30 ft. to 35 ft.	3 in. to 10 in.	
"	25 feet.	30 ft. to 35 ft.	8 in. to 14 in.	Driven 8 ft. to 10 ft. in clay.

Piles used were of spruce, and about 10 inches diameter at surface of ground.

On three occasions piles driven 20 feet or more in the ground, with penetration of about 12 inches by last blow with 25 feet fall, were again struck after 12 or more hours with the same fall, the consequent penetration being only 3 to 4 inches.


Commissioners Line
Congress St. Bridge
Proposed Bridge
FORT POINT
CHANNEL
Commissioners Line
Light Sea Wall
Heavy Sea Wall
New York & New England R.R.
Commissioners Line A
Eastern Avenue
BOSTON WHARF CO
COMMONWEALTH
Filled to Grade 16
Commissioners Line B
Northern Avenue
BOSTON & ALBANY R.R. CO.
Dock Wall
DOCK
Dock Wall
Present limit of filling
DOCK
DOCK
DOCK
Channel of 23 feet depth at Mean Low Water
BOSTON HARBOR
MAIN SHIP CHANNEL
PLAN OF
SOUTH BOSTON FLATS
Showing
LOCATION OF SEA WALLS.
AND
AREA OF EXCAVATIONS.
1877.
0 2 400
SCALE OF FEET

DOCK ON THE FLATS OF THE COMMONWEALTH.

Fig. 1.

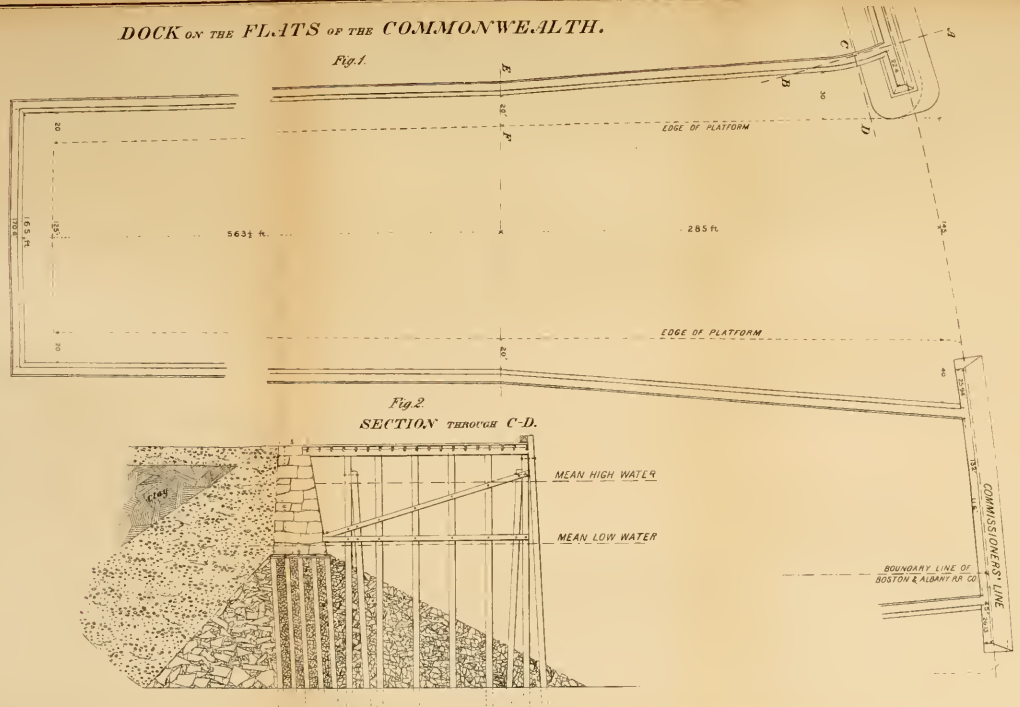


Fig. 2.
SECTION THROUGH C-D.

Fig. 3.
SECTION THROUGH E-F.

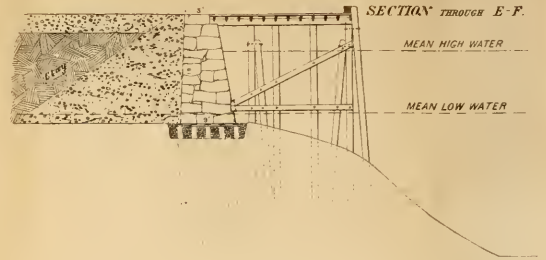
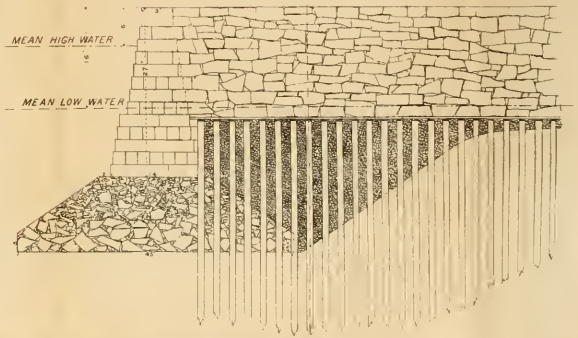
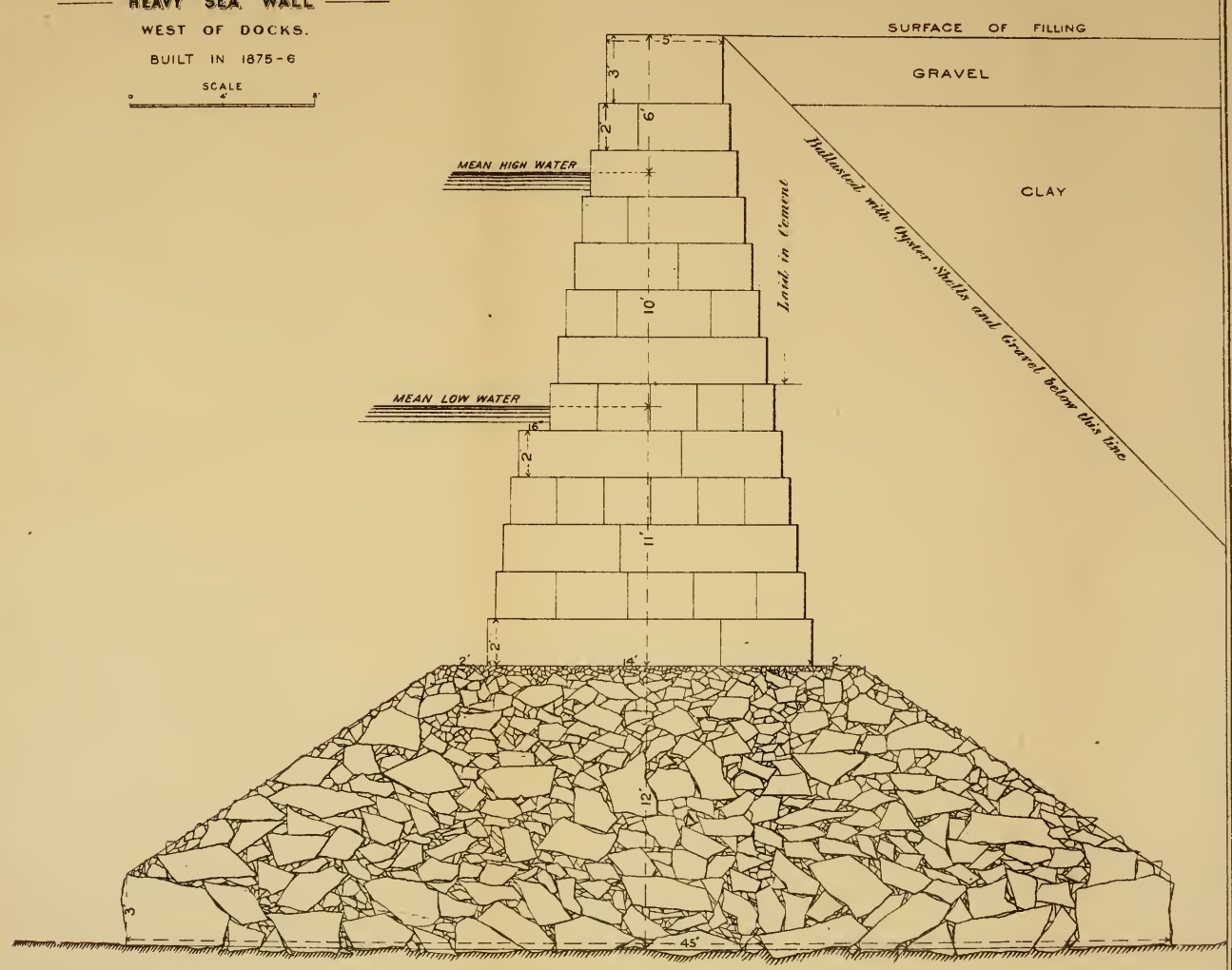


Fig. 4.
SECTION THROUGH A-B.



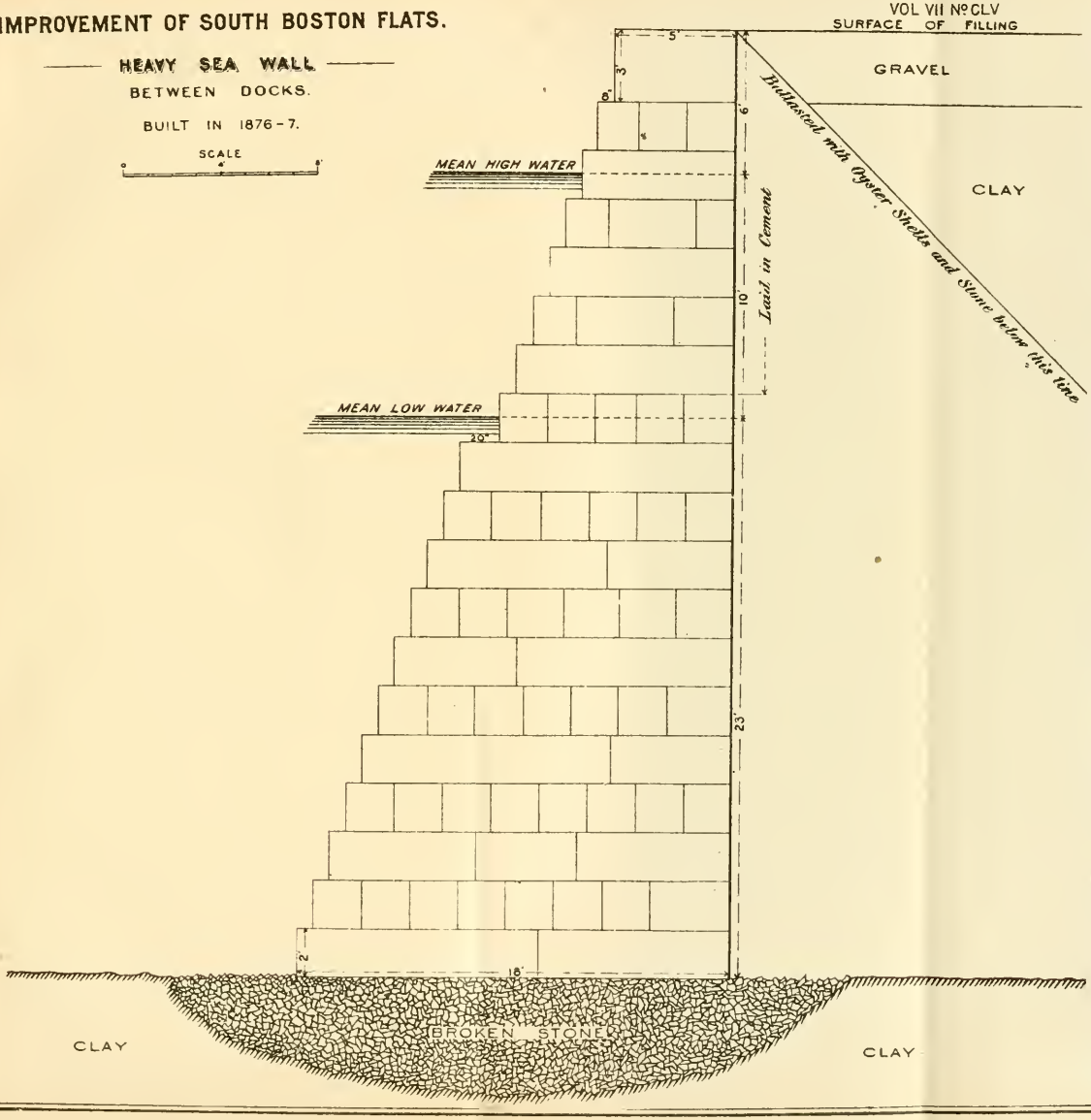
IMPROVEMENT OF SOUTH BOSTON FLATS.

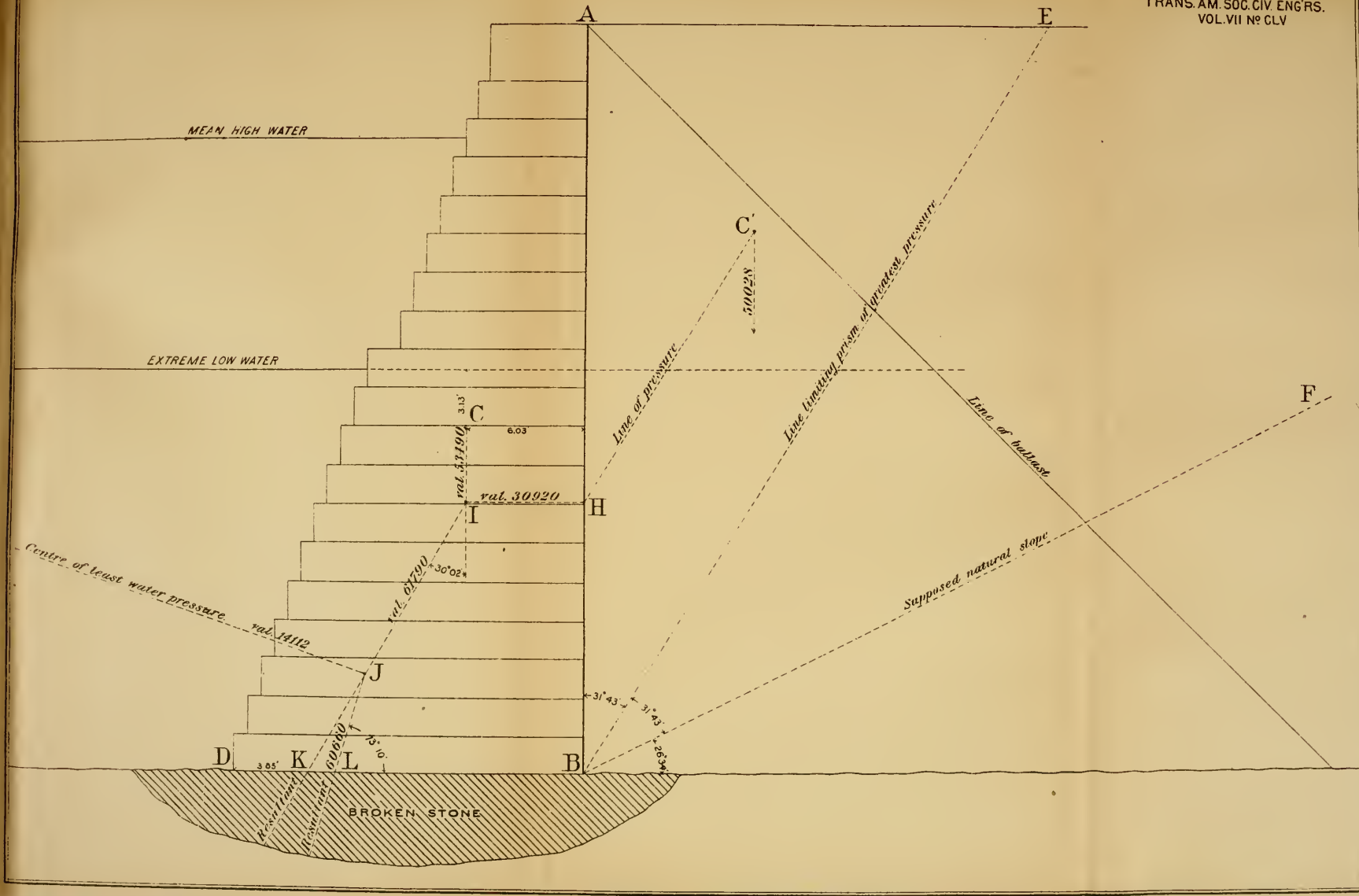


IMPROVEMENT OF SOUTH BOSTON FLATS.

HEAVY SEA WALL
BETWEEN DOCKS.
BUILT IN 1876-7.

SCALE
0 4' 8'




A
E
MEAN HIGH WATER
C'
50028
EXTREME LOW WATER
Line of pressure
Line limiting prism of greatest pressure
Line of ballast
F
C
3.13'
6.03
val. 51190
val. 30920
H
I
Centre of least water pressure
val. 61790
30°02'
Supposed natural slope
val. 14112
J
31°43'
31°43'
26°34'
D
3.85'
K
60860
L
15'10'
B
Resistance
Resistance
BROKEN STONE

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CLVI.

(Vol. VII. March, 1878.)

ON A NEW METHOD OF DETECTING OVERSTRAIN IN IRON AND OTHER METALS, AND ON ITS APPLICATION IN THE INVESTIGATION OF THE CAUSES OF ACCIDENTS TO BRIDGES AND OTHER CONSTRUCTIONS.

A Paper by ROBERT H. THURSTON, C. E., Member of the Society.

READ MARCH 20TH, 1878.

It has been shown by the writer * and by other investigators that, when a metal is subjected to stress exceeding that required to strain it beyond its original apparent, or "primitive," elastic limit, this primitive elastic limit becomes elevated, and that strain-diagrams obtained autographically, or by carefully plotting the results of well conducted tests of such metal, are "the *loci* of the successive limits of elasticity of the metal at the successive positions of set." †

It has been shown by the writer also that, at the successive positions of set, strain being intermitted, a new elastic limit is, on renewing the application of the distorting force, found to exist at a point which

* See Trans. Am. Soc. C. E., 1874, *et seq.*, Journal Franklin Institute, 1874; Van Nostrand's Eclectic Engineering Magazine, 1874, etc., etc.

† On the strength, etc., of Materials of Construction. 1874, Sec. 20.

approximately measures the magnitude of the load at the moment of intermission.*

It has been still further shown by the writer, and by Commander Beardslee, U. S. N., by direct experiment in the Mechanical Laboratory of the Stevens Institute of Technology, and at the Washington Navy Yard, that the normal elastic limit, as exhibited on strain-diagrams of tests conducted without intermission of stress, is exalted or depressed when intermission of distortion occurs, according as the metal belongs to the iron or to the tin class.† This elevation of the normal elastic limit by intermitting strain is, as has been shown, variable in amount with different materials of the iron class and the rate at which this exaltation progresses is also variable. With the same material and under the same conditions of manufacture and of subsequent treatment, the rate of exaltation is quite definite and may be expressed by a very simple formula. The writer has experimented with bridge material, and Commander Beardslee has examined metal specially adapted for use in chain cables, for which latter purpose an iron is required, as in bridge building, to be tough as well as strong and uniform in structure and composition. The experiments of the latter investigator have extended to a wider range than have those of the writer, and the effect of the intermission of strains considerably exceeding the primitive elastic limit has been determined by him for periods of from one minute to one year.‡ From a study of the results of such researches and from a comparison with the latter investigation, which was found to be confirmatory of the deduction, the writer has found that, with such iron as is here described, the process of exaltation of the normal elastic limit due to any given degree of strain usually nearly reaches a maximum in the course of a few days of rest after strain, its progress being rapid at first and the rate of increase quickly diminishing with time. For good bridge irons, the amount of the excess of the exalted limit, as shown by subsequent test, above the stress at which the load had been previously removed may be expressed approximately by the formula :

$$E^1 = 5 \text{ Log. } T + 1.50 \text{ per cent.};$$

in which the time, T, is given in hours of rest after removal of the tensile stress which produced the noted stretch.

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* On the Mechanical Treatment of Metals ; Metallurgical Review, 1877 ; Engineering and Mining Journal, 1877.

† Trans. Am. Soc. C. E., 1877.

‡ The result on this investigation is completed and will be presented to the President of the United States by the United States Board appointed to test iron, steel, etc.

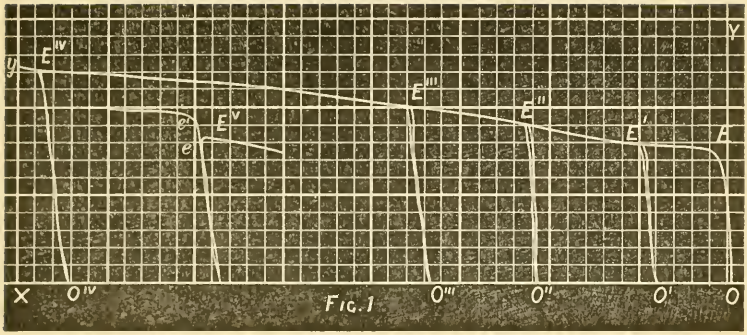

Fig. 1

Thus, in the figure, which is a facsimile of a part of a strain-diagram produced by such an iron, during a test in which the intermission of stress was of too brief duration to cause an observable exaltation of the normal elastic limit in a diagram drawn on so small a scale, the point E is the primitive elastic limit of the material, and E^{I} E^{II} E^{III} E^{IV}, are the normal elastic limits corresponding to sets under loads which have strained it beyond that primitive elastic limit. In the example here illustrated, the primitive limit is found at about 20,000 pounds per square inch, or 1,400 kilograms per square centimeter, and the other points are those corresponding to loads of, respectively, 21,000, 22,500, 25,000 and 30,000 pounds on the inch, or to 1 470, 1 575, 1 750 and 2 100 kilograms on the square centimeter. The corresponding extensions, as shown on the diagram, are 1.25, 2.53, 4.50 and 6.78 per cent.

Had the stress been intermitted at either of these points any considerable period of time, there would have been observed a rise in the diagram as above stated like that shown in Fig. 1, at E^{V} the normal elastic limit e, being, on subsequent test, found altered and a new limit, e', observed. The extent of this elevation of the limit would be the greater as the time of rest was greater, as already seen.

Thus, it is seen that a metal, once overstrained, carries, permanently, unmistakable evidence of the fact* and can be made to reveal the amount of such overstrain at any later time with a fair degree of accuracy. This evidence cannot be entirely destroyed, even by a moderate degree of annealing. Often, only annealing from a high heat, or reheating and reworking, can remove it absolutely. Thus, too, a structure, broken

* The writer has found by subsequent tests, that transverse strain produces the same effect upon the elastic limit for tension.

down by causes producing overstrain in its tension members, or in its transversely loaded beams (and, probably, in compression members—although the writer is not yet fully assured of the latter), retains in every piece a register of the maximum load to which that piece has ever been subjected ; and the strain-sheet of the structure, as strained at the instant of breaking down, can be thus laid down with a fair degree of certainty.

Here, then, when the work above detailed shall have been properly complemented with experimental determinations of the behavior of all the materials of general use in construction, may be found a means of tracing the overstrains which have resulted in the destruction or the injury of any iron or steel structure, and of ascertaining the cause and the method of its failure, in cases frequently happening in which they are indeterminable by any of the usual methods of investigation.

The fact of the normal variation of the elastic limit, as change of form progresses under gradually increased load, has been well established by the experiments of Hodgkinson, Clark, Mallett, and other English investigators ; by Tresca, particularly, in France ; by Werder and Bauschinger in Germany, and by Beardslee, the writer and others in the United States.

The exaltation of the series of normal limits so produced, still further, as shown by the writer and as seen in Fig. 1, by the intermission of strain, as at E^{v}, is also a matter of no uncertainty as to its character, although much more study is needed to determine the modifying effects of time of intermission on metals of the two great classes and of differing composition. The method above outlined of determining the extent of previous overstrain may therefore be expected to have many useful applications.

In illustration of an application of the facts thus reviewed to the determination of the causes and the method of the injury or the destruction of a structure, assume the existence of a set of conditions which is familiar to, probably, every engineer in the country who has seen much of the Howe truss, and of some other forms of bridges, as frequently built before the present generation of professional bridge builders effected a revolution in that department of engineering construction.

Suppose one of these bridges to have been built with a span of 150 feet and to have been given such proportions that, with a weight of 1,200 pounds per running foot and a load of one ton per running foot, the maximum stress on end-rods, or other members most strained, is as high

as 20 000 pounds per square inch of section of metal. Suppose this bridge to have its tension members composed of a fair, but unrefined, iron, having an elastic limit at about 17 000 pounds per inch, and a tenacity of 45 000 to 48 000 pounds, and with an extensibility of about 20 per cent.

Suppose this structure to break down under a load exceeding that usually sustained in ordinary work, and the cause of the disaster to be "involved in mystery."

Suppose portions of the several tension members to be subsequently removed, and, a few days after the accident, to be carefully tested, with the following results :

	Elastic Limit.	Tenacity.
Sample No. 1	16 500	46 000
" " 2	18 000	48 000
" " 3	30 000	48 000
" " 4	22 500	50 000
" " 5	25 000	52 000
" " 6	27 500	52 000
" " 7	28 000	52 000
" " 8	30 000	52 000
" " 9	32 000	53 000
" " 10	34 000	53 000

And that the extensibility is found to be as little as from ten to fifteen per cent.

Suppose it to be found that the tension members were straight bolts without upset ends, the threads being cut, as was once common, in such a manner that the section at the bottom of the thread is one-third less than the sectional area of the body of the bar. Suppose, finally, that the location of the tested pieces in the structure being noted, it is found that the stronger metal, having also the highest elastic limit, came from the neighborhood of the point at which the bridge gave way, and that the weakest metal and that exhibiting the lowest elastic limit came usually from points more or less remote from the break. It is not likely that in all cases the increase in the altitude of the elastic limit and the increase noted in the ultimate strength of the samples would exhibit a regular order coincident with the order of the rods as to position in the structure ; since the magnitude and the arrangement of the bars would, to a certain extent, determine the relative amounts of strain thrown upon them by overloading any one part of the truss. For present purposes we may assume the order of arrangement to be thus coincident.

On examination of the figures as above given, the engineer would conclude : First, that the original apparent elastic limit of the iron used

in this case must have been not far from 17 000 pounds per square inch and that its tenacity was between 46 000 and 48 000 pounds; secondly, that this primitive elastic limit had been elevated, by subsequent loads exceeding that amount, to the higher figures given by the bars numbered from 3 to 10 inclusive; thirdly, that the ultimate strength of the material had been, in some examples given above, increased by similarly intermitted strain.

It would be concluded that the ordinary loads, such as had been carried previously to the entrance upon the bridge of that which caused its destruction, never exceeded, in their straining action, 16 500 pounds per square inch of section of tension rod at the part of the truss from which No. 1 had been taken, and that the other rods tested had carried, probably, at the time of the accident, loads approximately equal to those required to strain them to the extent measured by their elastic limits at the time of testing them.

It would be concluded that the rod from which No. 10 was cut was either that most strained by the load, and therefore nearest the point of fracture of the truss, or that it was very near that point, and it would be made the basis of comparison in further studying the case.

As this elastic limit approaches most nearly the breaking strength of the metal, we may apply the formula for the elevation of the elastic limit with time after intermitted strain which has been above given as derived from tests of a metal of very similar quality. Taking the time of intermission as one week, the extent of the increase has a probable value not far from $E' = 5 \log. 168 + 1.5 =$ nearly $12\frac{1}{2}$ per cent. The magnitude of the stress upon this piece at the time of the accident was therefore 34 000 less one-ninth of that value, or about 30 000 pounds per square inch of cross-section of the bar. This corresponds to about 45 000 pounds per square inch at the bottom of the thread, and is within five per cent. of the primitive breaking strength of the iron. The bar, if broken at the screwed portion, has therefore yielded either under a dead load which was at least equal to its maximum resistance, or under a smaller load acting so suddenly as to have the effect of a real "live load." Or the slight difference here noted may be due to a flaw at the point of fracture. However that may be, it is almost certain that the body of the rod has sustained a stress of not far from 30 000 pounds per square inch.

But it is found, on further investigation, that the load on the structure at the time of the accident was but sufficient to make the maximum

stress on these rods—if properly distributed—20 000 pounds per square inch at the threaded part of the piece ; which piece, it has been seen, has been broken by a strain nearly double that figure. The fact is at once inferable that the load came upon these members with such suddenness as to have at least the effect of a live load (as taken in the text-books) and giving a maximum stress equal to twice that produced by the same load gradually applied, *i. e.*, the case in which the load falls, through a height equal to the extension of the piece strained by it, the resistances being assumed to increase directly as the extension up to the point of rupture, —an assumption which is approximately correct for brittle materials like hard cast iron, but quite erroneous in the case of some ductile materials, which latter sometimes give a "work of ultimate resistance" amounting to three-fourths or even five-sixths of the product of maximum resistance by the extension.

This accident was therefore caused by the entrance upon the bridge of a load capable of straining the metal to about one-half of its ultimate strength, if slowly applied, but which, in consequence of its sudden application, doubled that stress.

This sudden action may have been a consequence either of its coming upon the structure at a very high speed, or a result of the loosening of a nut, or of the breaking of a part of either the bridge floor or of one of the trucks of the train. The latter occurrence, permitting the load to fall even a very small distance, would be sufficient.

This paper is not presented as a perfectly satisfactory statement of definite facts from which absolutely reliable conclusions can be drawn. The whole subject is deserving, however, of very careful and very extended experimental investigation, and the writer has been able to obtain but a small amount of satisfactory definite information in regard to it as yet. The figures given do not exactly represent those obtained from any actual case. They do, however, fairly illustrate the limited experience of the writer, and are nearly exact for at least one case ; they may serve to indicate the possible value of the cautious application of the method here outlined of studying the causes of such accidents as are considered in the hypothetical case here taken.

The same method may sometimes be used to ascertain the probable cause of a boiler explosion by determining whether the metal has been subjected to overstrain in consequence of overpressure. The causes of accidents to machinery may also be thus detected, and many other applications will suggest themselves to every engineer.

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CLVII.

(Vol. VII.—March, 1878.)

STEAM ENGINE ECONOMY.

A UNIFORM BASIS FOR COMPARISON.

A Paper by CHARLES E. EMERY, M. E., Member of the Society.

In writing a general report on the exhibits referred to the judges of Group XX, Centennial Exhibition, the writer compared the facts available in regard to the economy of steam-engines of various kinds on the uniform basis that the boiler is capable of absorbing 10 000 heat-units per pound of coal consumed. This corresponds to an evaporation of 8.99 pounds of water at 80 pounds pressure, 9.03 pounds at 60 pounds pressure, or, 9.08 pounds at 40 pounds pressure from a temperature of 100° in each case. This evaporation is higher than is usually obtained, but has been so much exceeded in practice* that it is not considered too high for a basis of comparison. The basis, moreover, enables the duty of pumping-engines and other steam machinery to be ascertained and expressed in a very ready and convenient manner. Ten thousand heat-units per pound of coal is equivalent to one million heat-units per 100 pounds of coal, and as the duty of pumping-engines is conventionally expressed in millions of foot-pounds per 100 pounds of coal, it follows on the basis presented that *the number of foot-pounds per heat-unit*

* See examples at page 75 of the report referred to.

represents also the number of millions of foot-pounds duty per 100 *pounds of coal.* The performance of all kinds of steam-engines may be readily compared on this basis. The simplest application is in testing vacuum-pumps, the duty of which may be readily ascertained by noting the height of lift, and the initial and final temperatures of the water lifted. All the heat of the steam not expended in work enters the water, and the work performed lifts the same water. The difference in temperature gives very nearly the number of heat-units imparted to each pound of water lifted, and each pound of water so heated is lifted a certain number of feet high, so the result may be expressed readily in foot-pounds per heat-unit, which, as before stated, equals also, on the basis presented, the number of millions of foot-pounds duty per 100 pounds of coal. For ordinary comparisons the number of millions duty equals the lift divided by the difference between the initial and final temperatures of the water. For more accurate computations, the divisor should be increased by the number of heat-units expended for work per pound of water lifted, which equals the height divided by 772. The height preferably should be calculated from the indications of a pressure-gauge at the bottom of the discharge-pipe, so as to include frictional resistances. If D = duty in foot-pounds per 100 pounds of coal, H = the height of lift per gauge, and t and T = the initial and final temperatures respectively, then

$$D = \frac{1\,000\,000\,H}{T - t + .0013\,H.}$$

Arrangements have been made by the writer to use the same basis in testing pumping-engines, by discharging water from the hot well into the suction of the main pumps, and noting with delicate thermometers the resulting increase of temperature of the water lifted.

A vacuum-pump tested by the writer in 1871 gave a duty, on the above basis, of $4\frac{7}{10}$ millions; one tested by Mr. J. F. Flagg at the Cincinnati Exhibition in 1875, reduced to the same basis, gave a maximum duty of $3\frac{25}{100}$ millions. Several vacuum and steam-pumps tested on this basis at the suggestion of the writer about two years since, gave duties reported as high as 10 000 000 to 11 000 000, the very small steam-pumps doing no better apparently than the vacuum-pumps, which is by no means surprising. Elaborate experiments made with steam-pumps at the American Institute Exhibition of 1867,* showed that average-sized

* See report of Messrs. Holmes, Selden, and Emery, judges, &c., Transactions American Institute, 1867-68.

steam-pumps do not, on the average, utilize more than 50 per cent. of the indicated power in the steam-cylinders, the remainder being absorbed in the friction of the engine, but more particularly in the passage of the water through the pump. Again, all ordinary steam-pumps for miscellaneous uses require that the steam-cylinder shall have 3 to 4 times the area of the water-cylinder to give sufficient power when the steam is accidentally low; hence, as such pumps usually work against the atmospheric pressure, the net or effective pressure forms a small percentage of the total pressure, which, with the large extent of radiating surface exposed and the total absence of expansion, makes the expenditure of steam very large. One pump tested by the writer required 120 pounds weight of steam per indicated horse-power per hour, and it is believed that the cost will rarely fall below 60 pounds; and as only 50 per cent. of the indicated power is utilized, it may be safely stated that ordinary steam-pumps rarely require less than 120 pounds of steam per hour for each horse-power utilized in raising water, equivalent to a duty of only 15 000 000 foot-pounds per 100 pounds of coal on the same basis adopted for the vacuum-pumps. With larger steam-pumps, particularly when they are proportioned for the work to be done, the duty will be materially increased.

Ten thousand heat-units per pound of coal represents an ultimate efficiency of only ($10\,000 \times 100 \div 14\,500 =$) 69 per cent. of the calorific value of anthracite coal, so that ordinarily more than ($100 - 69 =$) 31 per cent. of the heat in the fuel is carried to waste up the chimney. A still greater loss is, however, experienced in utilizing the steam for the purpose of work in the engine. The mechanical equivalent of one heat-unit is 772 foot-pounds, which, on the basis referred to above, corresponds to a duty of 772 millions of foot-pounds per 100 pounds of coal. The most economical steam engines, for instance, pumping-engines of approved types, utilize in the steam-cylinder only about 130 millions, on the same basis, equivalent to an ultimate efficiency of ($130 \times 100 \div 772 =$) 16.84 per cent. of the heat in the steam, and but ($16.84 \times .69 =$) 11.62 per cent. of the calorific value of the fuel. The principal reason for this is that the exhaust steam necessarily carries to waste the heat required to maintain it in a vaporous state at the tension due to the back pressure. This under the most favorable circumstances forms the larger proportion of the total heat of the steam and reduces the opportunities for securing economy within small limits compared with the theo-

retical limit, although the differences between the performances of different engines are great when compared one with another.*

Means for securing economy in steam-engines may be divided into two classes, viz., those of a mechanical nature and those which influence the thermal conditions. As to the first, the necessity of securing tight pistons and valves, ample area of cylinder passages, reduced clearances, etc., are well understood, also the incidental advantages due to a certain degree of compression. Those of the second class act to reduce the cylinder condensation, and include high speeds of revolution, steam superheating, steam-jacketing, and the compounding of engines. High speed of revolution (which does not necessarily imply high piston speed, as generally understood) secures economy, by reducing the time in which the transfers of heat to and from the steam and inclosing walls must take place.†

Superheating the steam has experimentally proved effective for moderate rates of expansion, in which the original temperature required to maintain the gaseous condition of the steam to the point of release was not too high to prevent proper lubrication. Mr. Geo. P. Dixwell, of Boston, Massachusetts, has applied a thermometer to a steam-cylinder, by inspection of which it is possible to regulate the temperature so as to prevent injury to the metal surfaces. The great difficulty is, however, to secure a permanent and reliable superheating apparatus. Steam-jacketing has to a limited extent advantages of the same kind as superheating, and involves no serious difficulties in management. The jackets are most effective on long cylinders of small diameter. In experiments with

* In view of discussions in progress at the date of writing on the proper details of a theoretically perfect steam-engine, it is proper to mention that in the year 1868 the writer designed and partially constructed a non-exhausting experimental engine in which the steam, after expansion in the cylinder, was to be circulated through another vessel, to withdraw the water due to the performance of work; the dry steam was then to be returned to the cylinder and compressed, which it was expected would require less power than the expansion would furnish, and sufficient steam only be received from the boiler to supply that condensed for work. A demonstration of the correctness ot the principle only was intended, the power expected being so small that the experimental engine was to be connected to another to keep it in motion. Before the apparatus was completed the funds were diverted to objects of greater immediate necessity, and the subject is mentioned only as indicating the general principle upon which a theoretically perfect steam-engine may be constructed. See description of the apparatus in article on the "Theoretical Steam-Engine," *Scientific American* Supplement, August 18, 1877. See also Prof. Thurston's calculations on a similar subject in *Journal of the Franklin Institute*, October, November and December, 1877.

† The value of this saving was determined by the writer for the Novelty Iron Works, Mr. Horatio Allen, President, in the year 1868, and embodied in a series of tables showing the relative power and economy of different sizes of steam-engines, which tables were afterwards published by Prof. W. P. Trowbridge, the former Vice-President of the company.

United States revenue steamers, hereinafter mentioned, the economy of a steam-jacket on a comparatively short cylinder was found to be 11 to 12 per cent.

Compound engines, in addition to advantages of a mechanical nature, in better distributing the strains and rendering more uniform the rotative efforts, serve also to reduce cylinder condensation by the distribution of the differences of temperature between two cylinders. The radiation to and from the steam and its inclosing walls increases more rapidly than the difference in temperature, so that the aggregate loss, when the difference of temperature is divided between two cylinders, is less than when it all occurs in a single cylinder.* Moreover, the heat imparted to the exhaust steam by the metal of the first cylinder is available for work in the second, and the low-pressure piston acts as a screen between the high temperature in the small cylinder and the low temperature in the condenser.

It is still strenuously denied by many that greater economy can be secured with a compound engine than with a long-stroke single engine, using the same steam pressure. There are coasting steamers of similar size running regularly in the United States using both types of engine, with, it is claimed, substantially the same results; but the boilers for the single engines are evidently the more economical, making an accurate comparison impossible. Strictly comparative experiments have, however, been made by Chief Engineer C. H. Loring. U. S. N., and the writer with engines of different kinds in the steamers of the United States Revenue Marine, and by the writer with some of those of the United States Coast Survey.†

The revenue steamers were of the same size and the boilers very nearly identical. In one steamer was a compound engine with steam-jacketed cylinders; in another, a long-stroke, high-pressure condensing engine (cylinder not jacketed); in another an ordinary low-pressure engine (cylinder not jacketed); and in still another, a high-pressure condensing engine with a jacketed cylinder. The compound engine showed a saving of 12 to 16 per cent. compared with the best performance of either single

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* See article by the writer in *American Artizan*, March 8, 1871.

† See article by the writer on "Compound and Non-Compound Engines," *Transactions American Society of Civil Engineers*, vol. iii. p. 68, 1875: *Journal of the Franklin Institute*, February and March, 1875; *Engineering* (London), January, February and March, 1875; *Proceedings of Institution of Civil Engineers* (British), vol. xl., p. 292, and vol. xli, p. 296; also Report of trial of United States Revenue steamer *Gallatin*, *Journal of the Franklin Institute*, February, 1876, and vol. xxi., *Engineering*, 1876.

engine when operated at the same steam pressure. It is believed that substantially the same differences will be found in all cases when equally good engines of both types are compared. The performance of a short-stroke compound engine may be equalled or even excelled by that of a long-stroke single engine, on account simply of the difference in clearance spaces and the superior efficiency of the steam-jacket in the latter case, but by making the compound cylinders in the same form they should still show an advantage. In practice, the economy of marine compound engines is greater than above mentioned, for the reason that the high steam pressure is better maintained with them by the engineers than when single cylinders are used with high rates of expansion, causing difficulties in management.

The following table shows, in line 1 the performance of one of the Leavitt compound beam pumping-engines, at Lawrence, Massachusetts, and in line 2 that of the engines of the *Rush*, one of the revenue steamers previously referred to :

	Approximate Steam Pressure.	Ratio of Expansion.	Diameter of Small Cylinder.	Diameter of Large Cylinder.	Strokes of Pistons.	Revolutions per Minute.	Piston Speed.	Mean Pressure Referred to Large Cylinder.	Indicated Horse-Power.	Water per indicated Horse-Power per Hour.
			Inches.	Inches.	Inches.		Feet per Minute.	Pounds.		Pounds.
1	90	13.05	18	38	96	16.27	260.3	22.15	196.4	14.02
2	70	6.22	24	38	27	70.84	318.8	24.48	266.6	18.38

The comparison is very interesting. In both engines the larger cylinders are of the same diameter, but the difference in the duty for which the engines were designed required great differences in other proportions and in all the details of construction. In the pumping-engine for use on land there were no restrictions as to weight and space, so a comparatively long stroke could be employed and the connections made through a beam. The marine engine had, however, to be located in a small vessel, and was therefore directly connected and proportioned accordingly. Yet the long-stroke engine was run with so much expansion and at so slow a speed as to develop less power than the smaller one, and the latter was less economical, on account of the lower steam pressure and rate of

expansion and the relatively greater proportion of waste room in the cylinder, incident to the necessary use of ordinary slide-valves. The engine of the *Rush* was, however, more economical than the ordinary stationary compound engines used for manufacturing purposes, as the latter, according to published reports in the engineering journals, require the evaporation of not less than 20 pounds of water for each indicated horse-power. The Lawrence engine contains all well known means for securing maximum economy of steam, and it is probable that few if any engines are working with greater economy in respect to the indicated power. The performance is, however, much below that given by calculation when all the conditions are taken into consideration, other than the slight distortion of the theoretical indicator diagram found in practice and the important loss due to cylinder condensation.

In an engine using a total pressure of (90 + 14.7 =) 104.7 pounds, expanded 13.5 times in a cylinder, with clearances, etc., equal to .02 of the displacement, the calculated cost of one horse-power per hour, or 1 980-000 foot-pounds, should be only 8.12 pounds of water evaporated from the initial pressure, on the basis that the curve of expansion is hyperbolic, and that the consumption of steam equals the volume at the initial pressure, required to fill the cylinder to the point of suppression, plus that condensed for the total work. With a pressure of 100 pounds above the atmosphere, and an expansion of 20 times, there should be required on same basis the evaporation of only 6.00 pounds of water per indicated horse-power per hour. It is probable that the practical results obtained with the latter pressure and expansion would be little or no better than those from the Lawrence engine, on account of the greater cylinder condensation due to the increased expansion.

The above calculated performances, and the practical results obtained with engines and other steam machinery of various kinds, is shown in the accompanying table, in connection with the relative efficiencies obtained by considering the heat-units in the steam and the calorific value of the fuel. The table and a portion of the above are from the report previously mentioned, and the references are to pages therein.

Number of Line for Reference.	1 Description.	2 Steam Pressure.	3 Ratio of Expansion.	4 Water evaporated per indicated Horse-Power per Hour.	5 Duty in Millions of Foot-Pounds, per Indicator, per 100 Pounds of Coal. Pages 21 and 115.**	6 Relative Efficiency, based on the Proportion utilized of the total Heat of the Steam.	7 Relative Efficiency, based on the Proportion utilized of the Calorific Value of Anthracite Coal.	8 Net Effective Duty for lifting Water, in Millions of Foot-Pounds, per 100 Pounds of Coal.
					Comparative Results on Basis that 10,000 Heat-Units are imparted to Water per Pound of Coal. See pages 21 and 115.** Calculations based on a Temperature of Feed of 100°.			
1	Calculated performance. Maximum	.....	.....	.....	772.0	1.00	.69	
2	Calculated performance (see page 120)**	100	20	6.005	295.2	.382	.264	
3	Calculated performance	90	13.5	8.122	218.6	.283	.195	
4	Lawrence compound beam pumping-engines	89.4	13.7	14.019	126.7	.164	.113	
5	U. S. Revenue steamer Rush,* compound engine	69.2	6.22	18.384	97.03	.126	.087	
6	U. S. Revenue steamer Gallatin,* vertical cylinder with steam-jacket	67.2	4.19	21.48	83.08	.108	.074	
7	U. S. Revenue steamer Dexter,* vertical cylinder without steam-jacket	67.1	3.49	23.905	74.66	.097	.067	
8	U. S. Revenue steamer Dallas,* vertical cylinder without steam-jacket	32.0	3.13	26.945	66.91	.087	.060	
9	U. S. steamer Mackinaw,† inclined cylinder without jacket	49.0	2.2	30.306	59.16	.077	.053	
10	U. S. steamer Mackinaw, steam superheated	52.0	3.2	22.725	78.83	.102	.070	
11	Non-condensing engine, with governor cut off,‡ (st. jacket)	81.7	5.0	25.482	69.81	.090	.062	
12	Non-condensing engines, regulated by throttle	.....	.....	.....	30 to 45	.04 to .06	.03 to .04	
13	Pumping-engines							30 to 110
14	Steam-pumps. Large size proportioned for the work to be done							15 to 30
15	Steam-pumps. Small sizes for ordinary uses. See page 22**							8 to 15
16	Vacuum-pumps. See page 21,** also page 61 herein							3 to 10
17	Injectors when used for lifting water not required to be heated. See page 96**							2 to 5

* See references in foot-note, page 119,** also†, page 64 herein.
† See vol. ii. Isherwood's *Experimental Researches in Steam Engineering*, pp. 77–116.
‡ *American Institute Reports*, 1869–70, 1870–71.
** General Report of the Judges of Group XX, Philadelphia Int. Exhibition. Lippincott & Co., Philadelphia.

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CLVIII.

(Vol. VII.—March, 1878.)

THE INCLINE PLANE RAILROAD AT MADISON, IND.

ITS HISTORY AND OPERATION.

By M. J. BECKER, C.E., Member of the Society.

The history of the Incline Plane Railroad at Madison, Indiana, the changes in the methods of its operation, and the information which may be drawn from the experience of its working during a period of more than thirty years seem to present matter of considerable interest to engineers. I have been able to secure the following account, which has been mainly collected by Mr. R. Wells, Master Mechanic of the Jeffersonville, Madison and Indianapolis Railroad, and which contains all the reliable information it has been practicable to gather on the subject.

The Incline Plane at Madison was constructed under the supervision of Thomas Morris, as Chief Engineer, and was part of the main line of road between Madison and Indianapolis. The time when the Plane was first opened for traffic has not been ascertained, but business on it was carried on by using horses to draw the cars up until the fall of the year 1847.

The foot of the incline plane is 3620 feet from the depot in Madison (the terminus of the road). This track, from the depot to the foot of the incline has a grade averaging 1 in 110, and for about 800 feet next the

foot of the incline is on a curve of about 1000 feet radius. The incline is 7040 feet long, and the grade averages 1 in 17, but for about half the distance is 1 in 16.5, and at two places is a little heavier than that from the settling of the embankment. The track was originally straight, but owing to the sliding of the embankment at a point near the centre of the incline, it was slightly curved at that place. The gauge of the track was originally the same as it is now, 4 feet 8½ inches. In the year 1845, M. W. Baldwin, of Philadelphia, built a locomotive called the De Witt Clinton, having six coupled driving wheels 42 inches in diameter and cylinders 13 × 20 inches, for working this incline; but as the engine could draw but two cars up at a time, depending on its weight on the rails for adhesion, it did not prove satisfactory, and as stated before, horses were used to draw the cars up the incline until the year 1847. About the year 1845, an old gentleman named Hoyt, who lived near Dupont, on the line of the road, fourteen miles from Madison, conceived the idea of laying a cast iron rack on the outside of the rails of the track, and level with the top of the rails, to be laid on steep inclines such as this, and a wheel, or segments with cogs corresponding to those in the rack was to be attached to the outside of one of the driving wheels so that when the locomotive came to the part of the line where the rack was laid, the cogs on the one would work into those of the other, preventing slippage, the tire of the wheel at the same time carrying its weight the same as other places. To obtain the requisite power to ascend inclines, Hoyt proposed to have a pinion wheel arranged so as to gear into the wheel attached to the driving wheel, driving the pinion by a cylinder and crank which, when not needed, was to be thrown out of gear. Hoyt had a rough model of his plan and explained it to the officials of the road in the various interviews he had with them from time to time, and among others, to Mr. A. Cathcart, who had charge of the machinery of the road at that time. It seems that Hoyt's plan was not considered practicable, and he met with but little encouragement. but Cathcart, soon after, perfected his own plan which he carried out and put in practice in the fall of the year 1847. He evidently was indebted to Hoyt for the original plan. Yet he used but little of Hoyt's plan, except a rack and a wheel to work in it. As a settlement for any claims that Hoyt might have to any part of Cathcart's arrangement, the latter paid the former $1000 to relinquish all claims he might have in the invention used.

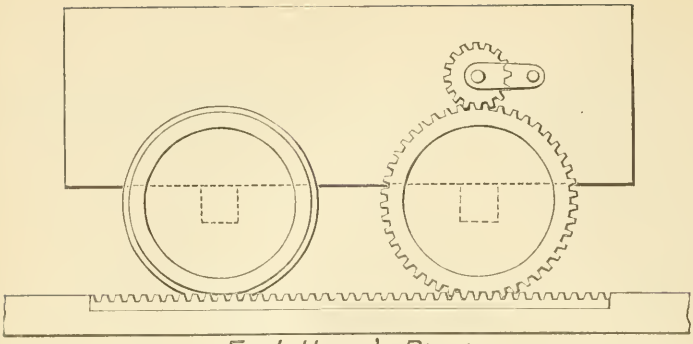

FIG. 1. HOYT'S PLAN.

Hoyt's plan is represented in Fig. 1. It is a copy of his original sketch.

Cathcart's plan is represented in Fig. 2. His locomotive had eight driving wheels coupled in the usual manner, 42 inches in diameter, and a pair of inclined cylinders 16 inches diameter and 20 inches stroke attached to the side of the smoke box, as shown in the sketch. In addition to this the engine had a pair of vertical cylinders 15 inches diameter and 18 inches stroke, shown at *B*, Fig 2. These cylinders were attached to a shaft held in place by a frame connected with the vertical cylinders, and also the frame of the locomotive. On the centre of this shaft was a pinion 16 inches in diameter, shown at *C*, gearing into another pinion shown at *D*, which, when in use, geared into the rack laid in the centre of the track as shown at *E* and *F*, Fig. 2. This pinion, *D*, was 32 inches in diameter, and was movable vertically in curved jaws, the radius of this curvature being the distance from the centre of the pinion *C* to that of the pinion *D*. For the purpose of raising the pinion *D* out of the rack when not in use, and also for holding it down in place to prevent it from slipping out of gear while at work, a cylinder of 8 inches in diameter and 12 inches stroke, shown at *G*, Fig. 2, was used by means of an L crank and suitable rods and connections, the force of the steam on one side of the piston holding the pinion down in place, and when changed to the other side raising it up out of gear where it was held by a pawl until it was to be lowered again for use. The cogs were 4 inches pitch and 8 inches face on the rack, and 8 inches face on the pinion wheel. The top of the cogs in the rack was 6 inches above the top of the rails of the track. This rack was made in sections of about 3 feet in length. It was 8 inches wide at the bottom, where it rested on the timber, as shown

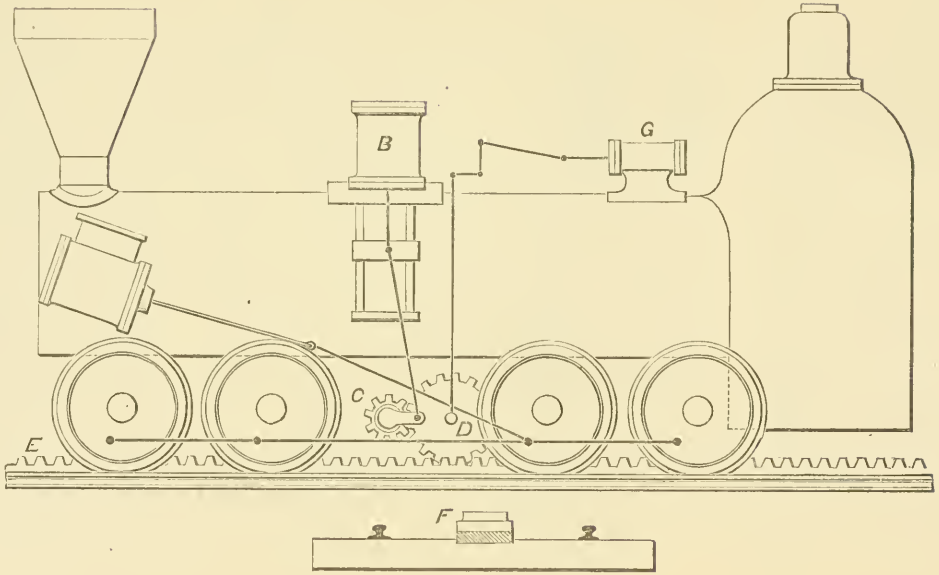

FIG. 2. CATHCART'S PLAN.

by Fig. 3, there being a flange on each side of 1 inch on which the head of the spikes rested that held the track down to the timber on which it was laid. These flanges were notched at proper intervals of ½ inch deep for the spikes, as shown at *R*, and there were also projections. *S S*, on the bottom which were let into the timber to prevent their being moved out of place. The timbers upon which the rack rested were 6 inches deep by 12 inches wide, laid on the cross-ties in the centre of the track, the ties being notched about half an inch deep to receive them, as shown in Fig. 3, at *T*. The rack was made from cold blast iron (cast). The cogs were not chilled. The pinion wheels on the locomotive were made of cold blast iron, and made in chills so as to chill the cogs to prevent wear as far as possible.

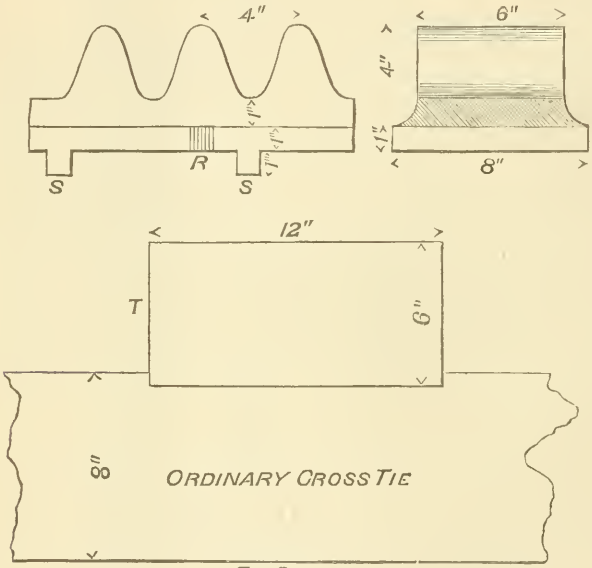

FIG. 3

This arrangement, known as Cathcart's plan, was complete and put in operation in the fall of the year 1847, and was continued in use until July, 1868, giving general satisfaction. The heavy business of the road from 1849 to 1854, and the lighter business afterwards, was all done on this plan with the two locomotives of the Cathcart plan, although the speed at which trains could be taken up and freight cars taken down was comparatively slow ; twenty minutes for passenger trains and twenty-

five minutes for freight trains was about the time occupied in ascending the incline of 7 000 feet with full trains, and the expense in maintenance of the rack and locomotive was heavy. The breakage of castings of the rack and the wearing out of pinion wheels of the locomotive, and cost of keeping up its complicated parts, the decay and removal of timber under the rack were all sources of trouble and expense, amounting to nearly the same whether heavy or light trains were drawn, and amounting to more than the business of the road would warrant in the last two or three years that arrangement was used. Owing to the expense of operating the incline, and the slow speed at which only it could be worked on this plan, it was determined to try the adhesion plan, by the use of very heavy and powerful locomotives, depending alone on the weight of the wheels on the rails for their adhesion. Consequently one was built in the company's shop of a pattern represented in Fig. 4, and put in service in July, 1868, since which time the Cathcart plan has been abandoned, and the plane worked entirely on the adhesion plan, which has been found to be much cheaper, quicker, and equally as safe, and more reliable. The principal dimensions of the locomotive, represented in Fig. 4, are as follows: Cylinder 20¼ inches diameter, 24 inches stroke; driving wheels (five pairs), 42 inches diameter; boiler, 56 inches diameter, $\frac{7}{16}$ thick, 201 two-inch tubes 12 feet long; fire-box, 5 feet 3 inches long, 5 feet 8 inches deep, 4 feet wide at top and 3 feet at grate, has 116 square feet fire-box heating surface, and 1 262 feet of tube surface. It is what is commonly called a tank locomotive, carrying wood (which is used for fuel) and water all on the five pairs of coupled wheels. The water is carried in two long cylinders (one on each side), shown at *H H*, connected to a centre water tank at the back, *I I*. These cylinders are flattened on the side next the boiler, as shown in the end view at *J*, but are the full circle back of the boiler. The two and the centre tank at the back end hold 1 800 gallons of water. The total weight of the locomotive, with fuel and water, is 112 000 pounds. A steam brake is situated at *K*, by which one-third of the weight of the locomotive can be made to rest on slides or runners forced down on the rails; friction brakes are also attached to the drivers, and applied by means of a screw sufficiently powerful to hold the locomotive on the incline, but are not used in ordinary service.

All freight trains are let down the incline by the locomotive using compression in the cylinders as a means of retarding power. For in-

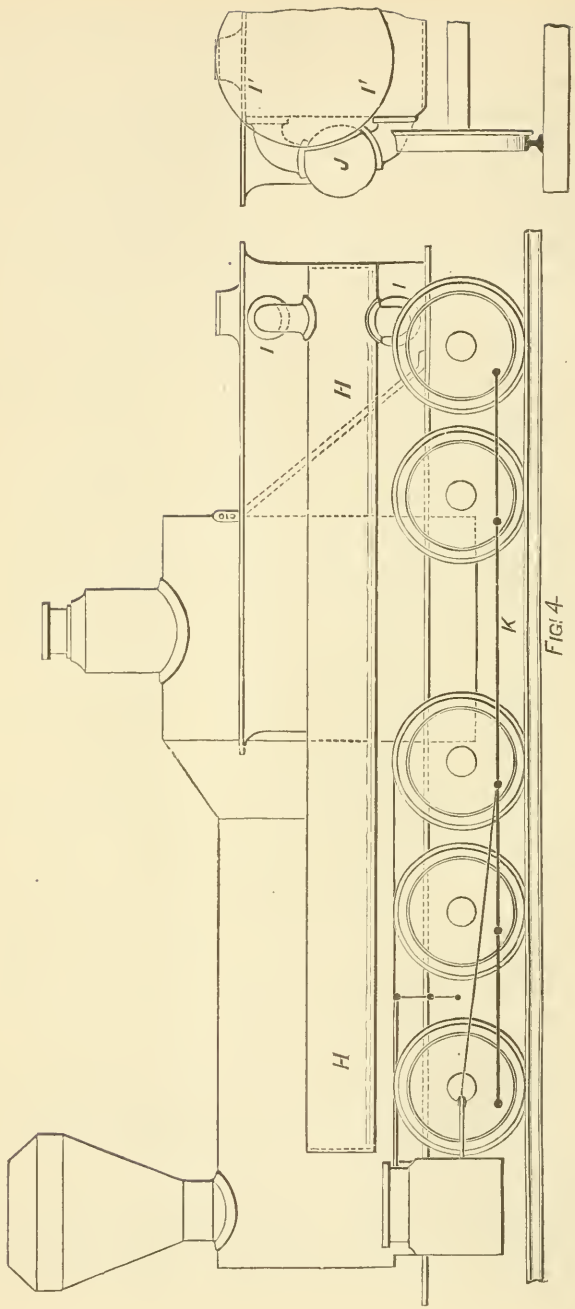

FIG. 4

stance, when backing down the incline the valves of the cylinders are moved by the forward motion which if there was no leakage of the pistons would either force air into the boiler or cause the wheels to stop turning in that direction. But to regulate the compression so as to give the required retarding force, the two ends of the cylinders are connected by a 1-inch pipe, in which is a sliding valve closing and opening to the desired size, permitting the compressed air on that side of the piston to flow through to the opposite side of it, and being regulated for both cylinders by one lever and to any speed descending to ten miles per hour.

The loads drawn up the incline and the time required may be explained by the record of one of the number of trips made April 9th and 10th, 1875, to test the quantity of fuel used, adhesion to rails, etc. :

Trip No. 1 was made on a dry day, temperature of the atmosphere 70° Fah. The load was eight cars loaded with coal.

Weight of cars and coal	308 360 lbs.
" " locomotive	112 000 "
Total	420 360 "

Speed at foot of incline, 2 miles per hour.

Time of leaving foot of incline—

At 3.40 P. M. ;	steam	pressure	in	boiler,	140 lbs.
" 3.45 "	"	"	"	"	140 "
" 3.50 "	"	"	"	"	143 "
" 3.52 "	"	"	"	"	140 "

Arrived at top of incline at 3.53 P. M. ; steam pressure in boiler, 130 lbs.

Distance run, 7 040 feet. Time, 13 minutes. Fuel used, $\frac{6}{10}$ of one cord of dry beech wood. No sand was used, and no slippage of the drivers occurred. The speed averaged 6 miles per hour. Trip No. 4 was made with two passenger cars, weighing 88 000 lbs. Locomotive, 112 000. Total, 200,000 lbs. Speed when going on the foot of the incline, 6 miles per hour. Time running the 7 040 feet, 5½ minutes=14½ miles per hour. Steam pressure in boiler, 132 pounds. Fuel consumed, $\frac{3}{10}$ of a cord of dry beech wood. No slippage of the drivers at any time, and no sand was used. The trip was made at 7.35 in the morning. No difficulty has been experienced at any time in working this incline for want of adhesion, either in winter or summer, dry or wet weather, and this plan has proved much more satisfactory than the one previously

used, and no accident to the locomotive has ever happened while ascending or descending that in the least interfered with safety.

It may not be without interest to the parties desiring information on this subject to know that a patent was granted to one Emor Rimber, of Rimberton, Chester County, Pa., March 5th, in the year 1831, the original papers coming into my hands while making inquiry on this subject.

The paper is signed by Andrew Jackson, who was President of the United States at that time, and Martin Van Buren (afterwards President), Secretary of State.

The sketch shown at Fig. 5 will explain Rimber's plan, and is a reduced copy of the original accompanying the patent documents.

As will be seen, Rimber proposed the use of a rack and pinion in the centre of the track, carrying the driving wheels of the locomotive (one pair of them) on a pair of smaller wheels of a diameter corresponding to that of the pinion wheel in the centre. The track upon which these small wheels run was elevated sufficiently to raise the driving wheels clear of the track, permitting them to turn in conformity to the smaller wheels and the pinion wheel working in the rack, the power being applied by the cylinders and crank on the outside of the driving wheels, as when running on an ordinary track. A "drag" was proposed to follow along the rack, so as to prevent running down the grade in case of accident to the machinery in ascending the incline, as shown in the sketch. As far as I can learn, Rimber's plan was never put in operation.

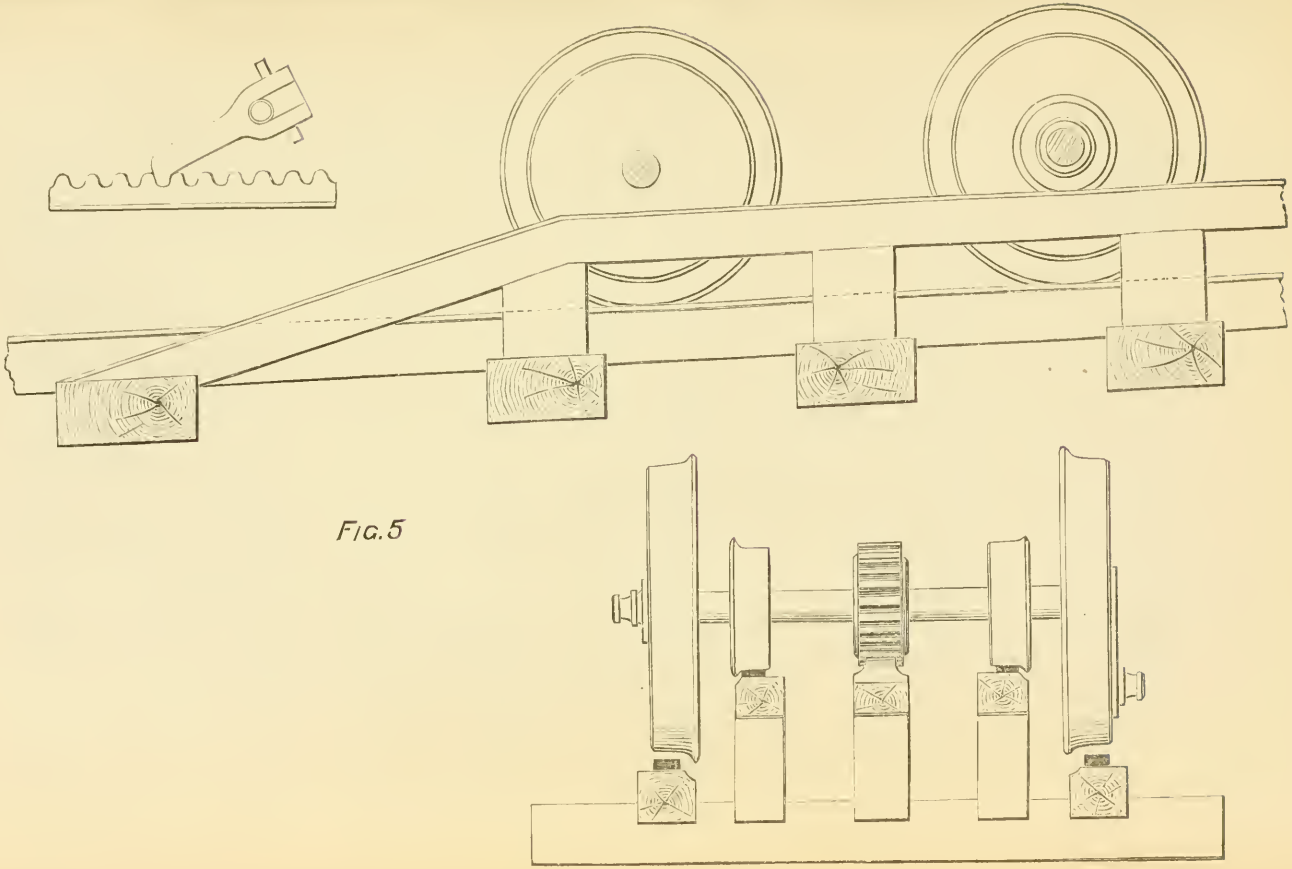

FIG. 5

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CLIX.

(Vol. VII.—April, 1878.)

ON THE THEORETICAL RESISTANCE OF RAILROAD CURVES.

By S. WHINERY, C. E., Junior of the Society.

The writer is impressed with the belief that too little attention has been given to the theory of the resistance which a curved track offers to the passage of a railway train. Efforts have often been made to determine the amount of this resistance experimentally, with greatly varying results, but very few attempts have been made, so far as the writer is aware, to investigate analytically the elements which together make up the sum of such resistance.

While it is probable that in the end, we shall be compelled to depend upon experiment for accurate information on this point, it will be admitted that intelligent theory is greatly needed to assist the experimenter in determining the amount and character of the resistance in question, and the inventor in devising means to surmount each of the elements which together make up the whole. It is one of the cases where analytical investigation must go hand in hand with careful experiment, if accurate and intelligent results in detail are to be reached.

As a contribution toward such investigation the following is submitted :

§ 1. When a railway car with cylindrical wheels of the same diameter moves along a track which is straight and transversely level, impelled by a power, which we shall call the tractive power, acting parallel to the rails, there is no tendency developed to move laterally or to press against either rail ; for the only force which acts upon it, other than the tractive power, is that of gravity, which is applied perpendicular to the plane of the supports, and consequently develops no tendency sidewise.

But when the direction of the forward motion is changed by a curved track, another force in addition to the two named is brought into action. This is the centrifugal force, which is expressed by the well known formula :

$$E = W \frac{V^2}{32.2R}$$

where F = the centrifugal force,

W = weight of the moving body,

V = velocity in feet per second

and R = the radius of the curve in feet.

We may consider the force of gravity and the centrifugal force as both applied to the centre of gravity of the car in a plane perpendicular to the tangent to the curve at that point. The force of gravity acts vertically downward, and the centrifugal force acts horizontally outward from the centre of the curve, and the resultant of the two is represented in direction and amount by the diagonal of a rectangle of which one side equals the force of gravity and the other the centrifugal force. But the former $= W$, and the latter $= W \frac{V^2}{32.2\,R}$; therefore this resultant is represented by the expression :

$$\sqrt{W^2 + \left(\frac{WV^2}{32.2R}\right)^2} = W\sqrt{1 + \frac{V^4}{1036.84R^2}}. \qquad (1.)$$

If we call α the angle which the resultant makes with the vertical (W), we shall have :

$$\sin.\ \alpha = \frac{\frac{WV^2}{32.2R}}{W\sqrt{1 + \frac{V^4}{1036.84R^2}}}, = \frac{\frac{V^2}{32.2R}}{\sqrt{1 + \frac{V^4}{1036.84R^2}}}$$

The action of this resultant develops a tendency to press the wheels against the outer rail of the track. To counteract this tendency we may incline the plane of the rails until it shall be perpendicular to the resultant; that is, we must make the angle between the plane of the rails and the plane of the horizon $= \alpha$.

Calling g the distance from centre to centre of rails,* the elevation E of the top of one rail above the other is found by the formula $E = g$ sin. α.

If we put for g its ordinary value, $4' 8\frac{1}{2}'' + 2\frac{1}{4}'' = 4' 10\frac{3}{4}'' = 4.896$ feet and the expression found above for the value of sin. α we shall have:

$$E = 4.896 \frac{\frac{V^2}{32.2R}}{\sqrt{1 + \frac{V^4}{1036.84R^2}}} \qquad (2.)$$

Table 1 gives values of E for various curves and speeds, calculated by the above formula.

It will be noticed that the values of E here given, differ somewhat from those usually given in tables of this kind. (See, for instance, Henck's Pocket Book, p. 120.) This difference is to be attributed, 1st. To the different value of g used, as explained above. 2d. Examination will show that other tables are based on the formula $E = g$ tan. α, which is clearly erroneous. Recurring to our rectangle of forces we find that

$$\tan. \alpha = \frac{W \frac{V^2}{32.2R}}{W} = \frac{V^2}{32.2R}$$

which expression multiplied by g is the formula usually employed.† At ordinary speed the results do not materially differ, but the erroneous character of the usual one becomes evident when the speed is made very great. When the "coming train" shall glide around a 12° curve at the rate of 90 miles per hour, the common formula would require, for a track of 4.7 feet gauge, a superelevation of the outer rail of more than five feet—a requirement, to comply with which would sorely puzzle the intelligent Hibernian section boss of the future. The difference due to this cause is less apparent in the above table, as compared with others, because the greater value of g used, tends to neutralize its effect.

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* The practice of calling g equal to the distance from inner face to face of rails, that is, equal to the guage of the track, is manifestly erroneous, unless care is taken to measure the superelevation of the outer rail from those points, and not, as is the usual custom, from the highest point of each rail.

† Henck, p. 89.

Table No. 1.

Elevation of outer above inner rail for various curves and speeds. Gauge of track 4 ft. 8½ in.

Degree of Curve.	Speed in Miles per Hour.							
	10	15	20	25	30	40	50	60
1°	0.006	0.013	0.023	0.036	0.051	0.091	0.143	0.205
2°	0.011	0.026	0.046	0.071	0.103	0.183	0.285	0.410
3°	0.017	0.038	0.068	0.107	0.154	0.274	0.427	0.612
4°	0.023	0.051	0.091	0.143	0.205	0.364	0.570	0.810
5°	0.029	0.064	0.114	0.178	0.256	0.455	0.704	1.005
6°	0.034	0.077	0.137	0.214	0.308	0.545	0.843	1.196
7°	0.040	0.090	0.160	0.249	0.358	0.634	0.977	1.379
8°	0.046	0.103	0.182	0.285	0.409	0.739	1.111	1.557
9°	0.051	0.116	0.205	0.320	0.460	0.810	1.242	1.734
10°	0.057	0.128	0.228	0.356	0.511	0.898	1.376	1.895
11°	0.063	0.141	0.250	0.390	0.560	0.982	1.492	2.049
12°	0.068	0.154	0.273	0.426	0.611	1.068	1.615	2.200

§ 2. As stated above, the resultant of the weight and the centrifugal force is represented in magnitude by the expression, formula (1).

It is evident that, when this resultant is applied normal to the plane of the track, it, and not W represents the true pressure on the rails. Calling this modified pressure W', we shall have

$$W' = W\sqrt{1 + \frac{V^4}{1036.84R^2}}. \qquad (3.)$$

§ 3. To effect the required difference of elevation between the outer and inner rail, it is the general practice to superelevate the outer rail above the general level of the track. This practice is, to say the least, doubtful. The moment a car strikes a curved track its centre of gravity is acted on by the centrifugal force which tends to overturn the car outward on the outer rail, but if at the same time the support of the inner wheel is removed or depressed, the weight of the car will tend to turn it on the outer rail inward. Thus the two forces acting in opposite directions will tend to neutralize each other. Another consideration which does not seem to have received attention in practice, is the fact that where a curve begins on an ascending gradient, the superelevation of the outer rail materially increases the steepness of the grade at that point. Thus if, on an ascending grade of forty feet per mile, a superelevation of the outer rail, of 0.8 feet is acquired in a distance of two hundred feet, the average gradient for that distance is increased to over fifty feet per mile.

There is a practical difficulty in securing, on circular curves, the necessary difference in elevation of the rails at exactly the proper time. Theoretically, the whole change of level should take place simultaneously with the beginning of the curve, a condition obviously impossible to comply with. But this difficulty may be overcome by beginning and ending the curve with a parabola whose radius, beginning infinitely great, shall become equal to the radius of the circle into which it merges. The change of level of the rails would thus begin with the beginning of the curve, and gradually increase until its maximum was reached at the beginning of the circle.

It is safe to predict that, in the future, when fabulous train speeds become possible, through perfection of track, all curves will begin and end with the parobola.

§ 4. If a cylindrical wheel is placed upon a plane surface and compelled to roll in a circular track, with its axis pointing continually toward the centre of the circle, there will be, in addition to the forward

motion in the prescribed path, a motion of revolution around the centre of the line of contact between the wheel and the plane. This motion is illustrated by the twirling of a coin placed on its edge on a table. When the wheel completes one revolution in its circular path it will have turned one complete revolution on its line of contact with the plane. This turning motion develops a certain amount of frictional resistance to the forward progress of the wheel, which we wish to determine.

The surface of contact between a cylinder and a plane is theoretically a line, but in reality it is doubtless a very narrow parallelogram. If weight is placed upon this parallelogram and it is then revolved around its centre, *i. e.*, the intersection of its diagonals, sliding on the plane upon which it rests, we shall have for the work done in overcoming the friction for one entire revolution,

$$n = \frac{l}{3} \pi W f.$$

Where n = the work done,

l = the length of the parallelogram,

W = the weight resting on the parallelogram,

f = the co-efficient of friction between the surfaces in contact.

The length of the line or parallelogram of contact between a car wheel and the rail is found to be about one inch = 0.0833 feet in ordinary practice. The value of the co-efficient of friction between chilled cast-iron wheels and iron or steel rails, varies with the velocity and the varying conditions of practice, from 0.15 to 0.25; for the purposes of this paper it will be sufficiently accurate to call it 0.2. Substituting these values of l and f in the above equation, we shall have

$$n = .017453\, W.$$

Dividing this by 360 we shall have the work done for one degree of angular change of direction in the motion, and dividing this again by the length of the arc of one degree in the circular path of the wheel, which in the case of railroad curves we may call $\frac{100}{D}$ (D = degree of the curve), we shall find the measure of this element of resistance for any curve to be

$$n = \frac{.017453\, W D}{36000} = .000000485\, W D. \qquad (4.)$$

This expression represents, as we shall see, an insignificant part of the total curve resistance, and would not be worthy of consideration were it not that we wish to determine, not alone the total amount of curve resistance, but also the relative magnitude of each element.

§ 5. When a pair of cylindrical wheels, of equal diameter, fixed immovably to the same axle, roll around a curved track, with the axle pointing continuously to the centre of the curve, it is evident that one of the wheels must slip on the rail over a distance equal to the difference in length between the inner and outer rail. If the track describes a complete circle, the difference in length of the two rails, whatever may be the radius of the curve, $=2g\times\pi$, and the difference for one degree of angular motion $=\frac{2g\times\pi}{360}=\frac{g\,\pi}{180}$. If now we multiply this expression by $\frac{W}{2}$ (since one-half the load rests on the slipping wheel), and by the co-efficient of sliding friction between the rails and wheel f, we shall have the total work done in thus sliding one wheel over the arc of one degree of the curved track, and if we divide this by the length in feet of that arc $\frac{100}{D}$, we shall have as the measure of this element of resistance S,

$$S=\frac{g\,\pi\,W\,Df}{100\times360}=\frac{4.896\times3.1416\times0.2\,W\,D}{36000}$$

$$=0.00008545\,W\,D. \qquad (5.)$$

§ 6. In practice, two or more pairs of wheels are so fixed in a rigid frame, that the axles are held parallel to each other. When such a system is placed on a curved track it is impossible for it to conform readily to the curve, or for the axles of each pair to point towards the centre of the curve; but if it rests symmetrically on the rails, the radius of the curve to which the axles are parallel, will pass midway between the first and last axles of the system. If motion be given to the system it will tend to move in the direction of the tangent to the curve at the extremity of that radius. But the rails pressing against the flanges of the wheels will compel it to follow the curve. The pressure thus exerted, develops a resistance to the onward motion of the body, which may be approximately determined.

If we denote by m the distance from the point where the rail presses against the flange of the wheel in guiding it along the curve, back to the radius of the curve, which passes through the centre of the truck, in a line perpendicular to that radius, and denote by β the angle which measures the change of direction of the curve in that distance, we shall have $\sin.\,\beta=\frac{m}{R}$.

It is obvious that this angle remains constant while the car passes around the whole length of any curve of constant radius.

In the effort to follow the straight line as described above, the outside forward wheel of the truck tends to roll diagonally across the face of the rails. Thus, Fig. 1, any given plane in the wheel, as AD, would, if unrestrained, roll in the direction AB; but the resistance of the rail, against the flange causes the point of contact A, to follow AC. To do this it is obvious that the wheel with the weight resting upon it, must be slipped on the rail a distance $BC, = AC \times \sin. \beta$. Calling AC unity, and assuming 0.2 as the co-efficient of friction, the resistance offered to the onward motion of the car will $= W \times 0.2 \times \sin. \beta$ (6). But while this expression represents the amount of work done by the rail in compelling the wheel to follow the curve, it does not represent the whole of the power expended in the operation; for in the act of revolving the wheel is moved continuously at the point of contact between the flange and the rail. The pressure at this point is evidently $W \times 0.2 \times \sin. \beta$ and this pressure will cause a frictional resistance $= W \times 0.2 \times \sin. \beta. \times 0.2 = 0.04\ W \times \sin. \beta$. But the tractive power acts on this frictional resistance through the agency of a lever of which the long arm is the radius of the wheel, the fulcrum, the point where the tread of the wheel rests on the rail, and the short arm, the distance from the latter point to the point of contact between the flange and the rail. The last named distance is of uncertain magnitude, being dependent on the size of the wheel and the form of the flange. It is probable that in practice it does not vary much from four inches. Assuming that as the correct value, and calling the radius of the wheel sixteen inches, we shall have for the tractive power necessary to overcome this particular element of resistance, $\frac{4\ (.04\ W \times \sin. \beta)}{16} = 0.01\ W \times \sin. \beta$, and for the whole resistance due to compelling the wheel to follow the curve; which we may call p,

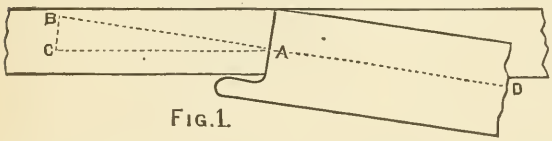

FIG. 1.

$$p = 0.2\ W \sin. \beta + 0.01\ W \sin. \beta, = 0.21\ W \sin. \beta. \qquad (7.)$$

The conditions above described strictly apply to only the outer front and inner rear wheels of the truck. But a little consideration will show that the four wheels of the truck are together subject to just four times

the resistance for one wheel, as given above; for the inner front and outer rear wheels must be constantly slipped toward their respective rails in order to conform to the curve, to the same extent as the other two wheels are slipped in the same directions; but the whole of the work is done by the flanges of the outer front and the inner rear wheels.

§ 7. There is another element which may affect the results given by the above formula, which may be thus stated. In considering the element of the friction between the wheel flange and the rail, we have, in effect assumed that the side of the rail is vertical; that is, that a point of the flange in contact with the rail moved downward in a plane perpendicular to the top of the rail and the tread of the wheel. If this is not the case, any given point of contact of the flange must slide down an inclined plane, thus resolving the power applied into two components, only one of which is available for the work required. While the energy thus lost is insignificant in amount, in the ordinary practice, it is nevertheless a source of resistance, and unless there are weightier reasons for a different practice, the sides of rails should be made vertical, and the flanges of wheels so shaped that the rail will retain this form under wear.

§ 8. When individual cars are joined into a train and drawn by a locomotive along a curved track, the line of tractive power or tension forms a funicular polygon, of which each car forms a side, and whose angles are located at the points where the cars are coupled together. At each one of these angles a certain amount of the tractive power or energy is absorbed and the remainder transmitted to the following side of the polygon. In other words, at each angle the tractive power is decomposed into two components, one of which is expended in drawing the following car along the track, and the other tends to move the angle itself towards the centre of the polygon, which is identical with the centre of the curve of the track.

If we denote by φ the acute angle between the longitudinal axes of two adjoining cars, and by T the tractive power exerted by the forward car, and by T' the tractive power transmitted to the following car, we shall have $T' = T \cos. \varphi$. (8), and the amount of power lost at the angle will be $T - T \cos. \varphi = T(1 - \cos. \varphi)$. (9). If we know the power which, applied to a single car in the direction of its longitudinal axis will move it along a curved track under given conditions, we may, by the aid of formulæ (8) and (9) readily determine the aggregate amount of energy thus lost in any train.

The second component into which T is decomposed, tends to move the angle of the polygon toward its centre. Its practical effect, were it of sufficient magnitude, would be to press the flange of the inner wheels against the rail. Now the polygon rests on the track at as many points as there are trucks in the train; that is, at two points in each car, and as the line of tractive power must be considered as straight from one point of application to another, we may consider the polygon thus formed as having double the number of sides heretofore considered, and the acute angle between adjacent sides will be $\frac{\varphi}{2}$, and the radial component, u, of the tractive power will be, nearly,

$$u = T \sin. \frac{\varphi}{2} \qquad (10)$$

It would seem at first thought that this component ought to relieve, to some extent, the pressure against the outer rail expressed by formula (6), but it will be remembered that the inner rear wheel of the truck presses against the inner rail with the same force that the outer front wheel presses against the outer rail in causing the truck to follow the curve. Hence, this component can be of no service in diminishing the sum of the resistance due to that cause.

§ 9. We have purposely neglected so far to take into account the element of coned wheels in modifying the resistance due to curved track, preferring to consider the whole subject briefly in a separate section. There is, perhaps, no one thing in railroad practice upon which there is such diversity of opinion, as upon the subject of the utility of coning the wheels of cars. It is needless to here enumerate the various shapes which such opinion takes. It is certain that the tendency of the day is to reduce the amount of coning to a very small quantity, and many boldly predict that coned wheels will soon be a thing of the past.

We shall use, for the purposes of illustration in this paper, the standard wheel of the Pennsylvania Railroad, which is 33 inches in diameter, has a tread of 4¾ inches, and a coning of ⅜ inch; that is, the diameter of the wheel at its outer edge is ⅜ inch less than at the tangent point of the curve which joins the tread and the flange. The space allowed between each rail and the flange is one-half inch, and, therefore, the total lateral "play" of the wheels on the track is limited to one inch. When a pair of such wheels are resting symetrically on the track they are of the same diameter at the points of support. But if moved toward one side so that the flange of one wheel is in contact with the rail the

diameter of that wheel will clearly be increased an amount $= \frac{\frac{3}{8}'' \times \frac{1}{2}''}{4\frac{3}{8}''} = \frac{3''}{70}$, and as the diameter of the other wheel will be decreased a like amount, the difference of their diameters in the new position will be $\frac{3''}{35}$; and if the pair of wheels in this position were put in motion they would, if unobstructed, describe a circle whose radius reckoning from the centre of the track, and calling the diameter of the lesser wheel 33″, we shall find to be 1887 feet, which is the radius of a 3° 8′ curve. Therefore, if the wheels were placed on a curved track of 1887 feet radius with the flange of the wheel in contact with the outer rail, they would follow the curve without any constraining influence by the rails, and consequently their forward motion would be entirely free from the frictional resistance expressed by formulæ (5) and (7). If the curve were of greater radius than 1887 feet, the flange of the outer wheel would recede from the rail until a difference of diameter was produced which should correspond to the radius of the curve, and the wheels would then move onward as before.

It would therefore seem to be a legitimate conclusion, that cars properly furnished with such wheels as we have considered should pass around any curves less than 3° without the resistance due to unequal length of rail, formula (5), and that caused by forcing the car to follow the curve, formula (7). But in order that the wheels of any car may be free to thus adjust themselves to the curvature of the track, it is necessary that the other forces acting in a lateral direction, shall be so nearly in equilibrium that this adjusting power of the wheels, shall be the controlling force in its motion. Let us see if that is the case. The movement of the pair of wheels which we have been considering would be identical with the movement of a frustrum of a cone whose bases were respectively equal in circumference, to the circumference of the wheels. If such a frustrum is placed on a plane surface and put in motion by a force acting horizontally on its centre of gravity and perpendicular to its axis, the path described by that centre of gravity will be a circle. But if the velocity is gradually increased until the centrifugal force becomes greater than the sliding friction between the frustrum and the plane, it will leave its circular path and follow a tangential one. Thus, the practical measure of the centripetal force generated by the cone, is the friction between the cone and the plane upon which it rolls.

Now, if one pair of wheels supporting their share of the weight of a car were placed upon any curved track of less than 3° curvature with the flange nearly, but not quite, in contact with the outer rail, and given a forward motion, they would be influenced by the following forces, acting in a lateral direction. The centripetal force due to the conical shape of the rolling body, the tendency to slide down the inclined plane of the track due to elevation of outer rail, and the radial component of the tractive power, would tend to move it toward the inner rail, while the centrifugal force, and the disposition to press against the outer rail expressed by formula (6), tend to move it toward the outer rail. But if the track is inclined properly with reference to the existing conditions, the tendency to slide down the inclined plane of the track and the centrifugal force will entirely neutralize each other, and the radial component of the tractive power is insignificant in this connection. The pressure towards the outer rail is, as we have already determined, formula (6) $= Wf$, $\times$ by the sine of an angle which can never, in practice, exceed four or five degrees, while the centripetal force due to conicity of wheels is, as we have seen, equal to the friction between the wheels and the rail $= Wf$ — a power so much in excess of the algebraic sum of all the other laterally acting forces as to be amply sufficient to govern the motion of the train.

But in practice it is generally the case that the inclination of the track is not exactly that needed to balance the centrifugal force. The track may be inclined for a maximum speed, while the actual speed may be almost zero, or, on the other hand, the track may have little or no inclination while trains pass at a maximum speed. In the first case, the weight of the car being unbalanced on the inclined plane of the track, would tend to slide inward, and if the preponderance of gravity was sufficient to overcome both the forces acting outward and the friction between the rails and wheels, the flanges would be held against the inner rail, in which case the conicity of the wheels would increase instead of diminishing the train resistance. But if we take any case of this kind likely to occur in practice and compute the magnitude of the various forces acting inward and outward, we will find that the excess of the inward acting forces, is not sufficient to overcome the sliding friction between the wheels and the rails. In the second case, the centrifugal force would be unbalanced ; but as in the first case, we may prove that the excess of outward acting forces is not sufficient to overcome the centripetal force of the coned wheels in cases likely to occur. Hence, we are forced to

conclude that the coned wheels of a car will adjust themselves to any curve whose radius is not less than the altitude of the cone, of which the wheels in the position of the greatest difference of diameter form a frustrum ; and since we have found that the wheels used for illustration would, under such circumstances, pass around a three degree curve without slipping or pressing against the outer rail, it is obvious that resistance due to these causes only begins to exist as the curve becomes sharper than three degrees. There is, however, an element of resistance chargeable to coned wheels, which, although it prevails on straight lines as well as curves, it will be proper to consider here ; for the modern coned wheel owes its existence to the prevailing belief that the advantages of its use on curved tracks more than compensate for the disadvantage of its use on straight track. This belief, as we shall shall now show, is without proper foundation. If the pair of wheels we have been considering are placed symetrically on a straight track and motion imparted to them, they will roll forward in a straight line. The motion of the system will be similar to that of a cylinder on a plane. But each wheel is itself a truncated cone, and if unrestrained would follow the law of motion characteristic of that body. If compelled to follow a straight line, there will necessarily result a certain amount of resistance.

We have, in a previous section, assumed that the line of contact between the wheel and the rail is one inch in length, and the assumption is probably very nearly correct. The diameter of the wheel at the inner end of this line is greater than at its outer end by an amount equal to $\frac{3}{35}$ of one inch ($4\frac{3}{8}'' : 1'' :: \frac{3}{8}'' : \frac{3}{35}''$) equal to a difference in circumference of 0.02244 feet. It is plain that that part of the wheel which revolves at the outer extremity of the line of contact, being of less circumference, must fall behind the part at the inner end of the line unless the difference is made up by the slipping of the former over a distance equal to the difference of circumference of the two parts. This difference of circumference we have found above to be 0.02244 feet, and as each intermediate part of the wheel between the extremities of line of contact will slip over a space proportioned inversely to its distance from the outer extremity of the line, the average space slipped over by the wheel will be $\frac{0.02244}{2} = 0.01122$ feet, and the work thus done in one revolution of the wheel will be $= W'f + 0.01122$, and if we divide this by the distance gone over in one revolution, we shall have the actual resistance

offered to the progress of the wheels. Calling this resistance g, and the larger diameter of the wheel 33 inches $= 2.75$ feet, we shall have.

$$g = \frac{0.01122\, W'f}{2.75\pi} \qquad (11.)$$

Substituting in this equation for $W'f$ the values, 2000×0.2 we shall find that it expresses a resistance of more than half a pound per ton of the load on the wheels, and it will be readily seen that this resistance is a constant quantity whether the track be straight or curved. We have found that the coning of this pair of wheels will obviate the resistance expressed by formulæ (5) and (7) on curves of three degrees and less, which amounts (see Table No. 2) to less than 0.3 pounds per ton of load, but it now appears that it will create a constant resistance of nearly double that amount. We are therefore forced to the conclusion that the coning of wheels not only does not diminish the train resistance on curves, but that it materially increases the resistance on straight lines.

It is charged and believed by many that to the use of coned wheels is to be attributed the larger part of the violent oscillations and concussions noticed in the motion of trains. The writer believes this to be true, but the question is clearly one to be settled by observation and experiment, and not by analytical investigation.

We have confined ourselves in discussing this subject to wheels of but one form, but the arguments and conclusions deduced will be found equally applicable to those having a greater or a less amount of coning.

If the conclusions we have reached are correct, they furnish sufficient reasons for discarding altogether the use of coned wheels.

§ 10. In addition to the sources of resistance enumerated above, there are several which may be called accidental elements of curve resistance, but as their magnitude can only be determined by experimental investigation, they will only be mentioned here. Bad alignment of track, irregular bends in the rails, uneven joints and ragged rails are much more productive of resistance on curves than on straight lines. Improper inclination of the plane of the track may also be a prolific cause of resistance. If the inclination be too little, the unbalanced centrifugal force of the car may slide the shoulder or end of the axle against the box and thus give rise to frictional resistance. If the inclination be too great the gravity of the car may produce the same result in an opposite direction.

By the aid of the several formulæ deduced above, Table No. 2 has been prepared giving the computed resistance from those sources of various

curves under given conditions. No allowance has been made for the use of coned wheels. In practice, the appropriate amount for accidental sources of resistance, as determined by experiment, should be added to the totals given in the table. This sum added to the previously determined train resistance on straight lines should give the total train resistance on the various curves.

§ 11. A careful inspection of Table No. 2, and the formulæ from which it is calculated, will lead to the following conclusions :

1st. The resistance is very nearly in inverse ratio to the radius of the curve, or directly as the degree of curvature.

2d. It varies directly as the weight of the car.

3d. It is almost entirely independent of the velocity.

4th. Other things being equal, a short car causes slightly less resistance than a long one ; but the difference, especially on light curves, is an unimportant part of the whole.

5th. It will be observed that the only formula into which the width of the track g enters as a factor, is formula (5), which expresses the resistance caused by unequal lengths of the outer and inner rails of the track. This element constitutes about 40 per cent. of the whole amount of resistance shown in the table, or, calling this tabular amount the total curve resistance, and assuming the resistance on straight track as 10½ lbs. per ton, about 11½ per cent. of the whole train resistance on a ten degree curve. As the magnitude of this element varies directly with g, it is evident that we may reduce it by reducing the gauge of the track. Thus, if we reduce the standard gauge to three feet, we shall have for a 10° curve :

$$4.7 : 3 :: 205.62 : 131.25 \text{ lbs.},$$

which, added to the other tabular items, makes a total of 452 instead of 526 lbs. ; and counting the straight track resistance as before, we find the new value of this element to be 7.7 per cent. of the whole—that is, by reducing the standard to a three-feet gauge, we reduce the train resistance $11\frac{1}{2} - 7.7 = 3.8$ per cent. This conclusion is of interest, in view of the claim made by zealous advocates of the narrow gauge, that short curves are much less objectionable on roads of narrow than of standard gauge.

§ 12. Of the total curve resistance shown by Table No. 2, it will be observed that the element expressed by formula (7) constitutes about 57 per cent. under the conditions assumed. Examination of the formula

Table No. 2.

Showing curve resistance of passenger trains on various curves. Gauge of track 4′ 8½″. Number of cars 6. Weight of each, and load, 40 000 pounds. Length of each over all 52 feet. Length of wheel base of truck (4 wheeled bogie), 6 feet. Velocity 25 miles per hour. Resistance on straight lines assumed to be 10½ pounds per ton of 2 000 pounds.

Degree of Curve.	Weight of Train. (W.)	Actual pressure on rails = W′. Formula (3).	Resistance due to turning of wheel on rail. Formula (4).	Resistance due unequal length of rails. Formula (5.)	Resistance due to pressure of rail in changing direction of motion. Formula (7).	Resistance due to loss of power at each angle of train. Formula (9).	Total resistance of train due to curve.	Resistance in pounds per ton of 2 000 lbs.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1°	240 000	240 006	0.1	20.5	29.3	0.2	50.1	0.4
2°	240 000	240 025	0.2	41.0	58.7	0.6	100.5	0.8
3°	240 000	240 057	0.3	61.5	88.0	1.8	151.6	1.3
4°	240 000	240 102	0.5	82.1	117.3	3.4	203.3	1.7
5°	240 000	240 159	0.6	102.6	146.7	5.5	255.4	2.1
6°	240 000	240 229	0.7	123.2	176.1	8.1	308.1	2.6
7°	240 000	240 312	0.8	143.7	205.5	11.4	361.4	3.0
8°	240 000	240 407	0.9	164.3	235.0	15.4	415.6	3.5
9°	240 000	240 515	1.0	184.9	264.5	20.1	470.5	3 9
10°	240 000	240 635	1.2	205.6	294.0	25.6	526.4	4.4

will show that the resistance varies as the sin. of the angle β; and since this angle is small, and varies directly with the length of the wheel base, we may say that this element of resistance varies directly with the length of the rigid wheel base of the car. In view of this fact, and the great comparative magnitude of this source of curve resistance, the importance of making car trucks as short as possible becomes manifest, and the superiority of the American eight-wheeled car, with bogie trucks, over the four-wheeled car, with a long rigid wheel base, is very apparent.

To the general statement above, that the weight of the car being the same, this cause of resistance varies with the length of the wheel base, is to be noted a modification in the case of six-wheeled bogie trucks, in which the central pair of wheels, while they bear their share of the load, do not generate resistance of this kind. To meet such cases, we may substitute in equation (7) for W, $\frac{2\,W}{3}$ and the formula will then give correct results.

§ 13. Should careful experiments confirm the results reached in this paper, as to the total resistance caused by curved track, it would be very desirable to find some short equation which will give with reasonable accuracy the required resistance without the solution of the several formulae deduced above. As a close approximation, the following may be found convenient:

$$R = D\,\frac{(g+l)}{25} + an$$

in which,

R = the total curve resistance,

D = the degree of curvature,

g = gauge of the track,

l = length of rigid wheel base, and

an = factors expressing approximately the curve resistance due to accidental causes—to be determined by experiment.

In conclusion, the writer is not ignorant of the fact that the results herein reached vary widely from the opinions generally held by engineers on the subject. The commonly accepted estimate for curve resistance is, that a curve of 10° about doubles the resistance encountered on straight track, while the result arrived at in this paper (see Table No. 2) is less than half that amount. Even when a liberal allowance for accidental resistance is added to the tabular amount, the disparity is too

great to be reconciled. It is very apparent that if the generally received ideas are correct, either the assumptions and arguments of the writer are erroneous or some important elements of resistance have eluded his perception. He readily admits that the weight of evidence is against him; but it will be admitted on the other hand that the experiments on which the conclusions generally held are based, were unsatisfactory, sometimes contradictory, and always inconclusive. It is not impossible that exhaustive experiments, made under the conditions assumed in computing Table No. 2, may give results not very dissimilar from those there given. Careful experiments in this field are greatly needed, and it is to be hoped that the need will be supplied at an early day. In the mean time, the writer's labor will not be in vain if it shall incite a discussion of the subject, and secure its further investigation by competent hands.

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DISCUSSIONS
ON THE THEORETICAL RESISTANCES OF RAILROAD CURVES.*

MR. O. CHANUTE.—It is interesting, but perhaps misleading to note that Mr. Whinery, from purely theoretical considerations, has arrived almost exactly at the amount of curve resistance for cylindrical wheels, which has been ascertained to exist, by experiment, upon ordinary wheels, at low speed.

As the resistance depends upon the number of degrees of curvature traversed, and as all the elements enumerated by the author vary with the amount of sharpness of the curve, with one exception, and the latter is of small relative importance, we may reduce these elements to factors of the degree of curvature, and they will then be as follows, for each degree of angular deflection per hundred feet :

Resistance of curves in pounds per ton per degree, 4 feet 8½ gauge :

Twist of wheel, or rotation on itself.....		0.0010 lbs.
Slip of wheel on shorter inner rail		0.1713 "
Flange friction to change direction.....		0.2450 "
Loss of power at couplings, from.....	0.0020 to	0.0213 "
Total resistance per degree..... ..		0.4386 lbs.

The last element alone not varying directly with the degree of curvature.

We may assume, therefore, that the result of the investigation is, that curves add about one-half pound per degree to the resistance on straight lines. Some additional elements being stated to have been left out.

* Paper CLIX, Vol. VII.

In 1854, Zerah Colburn satisfied himself in a series of experiments on the 6 feet gauge of the Erie Railway, that the curve resistance was about one-half pound per ton per degree, and this factor has been used upon this line ever since, in calculating curve resistances.

In 1844, Mr. B. H. Latrobe made a series of 36 experiments on curve resistance, on the 4 feet 8½ inch gauge of the Baltimore and Ohio Railroad. The average result of these experiments, as stated in Vose's "Manual for Railroad Engineers," was, that the resistance was 6.80 pounds per gross ton of 2 240 pounds, on a straight, level line, and 13.22 pounds per gross ton on a curve of 400 feet radius, or an angular deflection of 14° 19½′, at speeds varying from 1¾ to 3½ miles per hour.

The resistance, therefore, was as follows :

	Per Gross Ton.	Per Net Ton.
On curve 14° 19½′.....	13.22 pounds	11.81 pounds.
On straight line.....	6.80 "	6.07 "
Increased resistance...	6.42 pounds,	5.74 pounds.
Increased resistance per degree	0.4488 "	0.4008 "

Or almost exactly the same as calculated in the paper of Mr. Whinery.

Very recent experiments (May, 1878), upon the Metropolitan Elevated Railroad in New York, have shown an increased resistance produced by a curve of 90 feet radius (63° 40′) of 350 pounds for a single car of 10 tons, and of 1 100 pounds for a train of four cars, weighing 40 tons, both with fixed wheels, and on a gauge of 4 feet 8½ inches. Thus, in the first case the curve resistance was 0.5497 pounds per ton per degree, and 0.4319 pounds per ton per degree in the second.

The latter experiment having also included a train with loose wheels, it may be interesting to give the details. Each train consisted of four cars, weighing 40 tons, one with ordinary wheels fixed on the axle, and the other with loose wheels. The curve was of 90 feet radius.

	Rigid Wheels, 40 Tons.	Loose Wheels, 40 Tons.
Traction on curve (63° 40′).....	1 700 pounds	1 300 pounds.
" " straight line.....	600 "	450 "
Increased resistance.....	1 100 pounds	850 pounds.
Increased resistance per ton.....	27.50 "	21.25 "
Curve resistance per ton per degree....	0.4319 "	0.3337 "

It will be noted that the loose wheels show a less resistance than the fixed wheels, by 22 or 23 per cent., both on curves and on straight lines. The difference on straight lines proves little, the trains being different ;

whether the difference of 150 pounds upon the curve will compensate for the increased complication, future experience must decide. The resistance on straight lines is in both cases too great, being 15 pounds per ton for the fixed wheels, and 11¼ pounds per ton for the loose wheels, while at the low speed at which these experiments were tried, it is generally from 4 to 10 pounds per ton on our American railroads.

I regret not to have at hand the record of some English experiments, but I believe that the British practice is to allow about one pound per ton per degree, for the increased resistance on curves.

There is in Spon's "Dictionary of Engineering" a very full account of the numerous experiments made in France in 1862–3 and 4, by three French engineers, Messrs. Vuillemin, Guebhard and Dieudonné, upon the resistance of trains under all conditions of working.

Among other things, they ascertained that at a speed of 15 or 16 miles per hour, a curve of 1 000 metres, or 3 281 feet radius (say 1¾ degree curve), added 1 kilogramme per French ton, or 2 pounds per net (American) ton, to the resistance on straight lines. On a curve of 800 metres, radius, or 2 624 feet (say 2° 10′) the increased resistance was 3 pounds per net ton. The increased curve resistance, therefore, was 1.1428 pounds per ton per degree in the first case, and 1.3820 pounds per ton per degree in the second.

It must be remembered, however, that these English and French factors were obtained with European four-wheeled cars, whose long, rigid wheel base must develop greater curve resistance than our short and pivoting American truck.

The agreement between the results of experiments, and of the theoretical calculations in the paper under discussion, would be more satisfactory if the latter had been made for conical, instead of cylindrical wheels. The author admits that on a curve of 1 887 feet radius, with coned wheels of the Pennsylvania R. R. standard, the two principal elements of resistance, that from the slip of the inner wheel, and the flange friction in changing the direction (amounting together to 0.4163 pounds per ton der degree), would disappear if the wheels assumed their proper position on the track.

He points out, however, that in order that this shall occur, two conditions must obtain simultaneously: 1st, that the curve shall be of the radius corresponding to the coning of the wheels, and 2d, that the speed shall correspond to that for which the outer rail is elevated.

Not only do these two conditions but seldom occur exactly together in practice, but there is an additional element of resistance, incapable of exact computation, which not only adds considerably to the resistance, but prevents the wheels from adjusting themselves to their proper position on the track, and remaining so around the curve.

This consists of the additional flange friction which results from the oscillations of the truck upon its pivot. These occur upon straight lines, but more especially on curves where the impulse given to the wheel in changing its direction, drives the truck diagonally towards the opposite rail. These oscillations cause the wheel flanges to impinge first on one rail, and then on the other, and thus both both add to the resistance, and prevent the coning of the wheels from being continuously effective.

It is not improbable that the constant variations in the resistance of trains, indicated by the dynamometer, are largely caused by this varying flange friction, due to the swaying of the truck from side to side.

An additional element of resistance is due to the fact, that the axles being held rigidly parallel by the framing of the truck, cannot assume a truly radial position to the curve, and hence the tendency of the whole is to roll in a straight line, even when the coning of the wheels brings unequal diameters to bear upon the two rails. It may be doubted, therefore, whether the fourth element of resistance, enumerated by the author, that due to the flange friction requisite to change the direction, is ever eliminated in any position of the wheels on the curve.

It may, however, be noted that the resistance on straight lines due to the coning of the wheels, has been considerably over estimated in the paper under discussion.

The author is quite correct in stating that the part in contact between the wheel and rail, is a surface. The metal, being elastic, yields in both wheel and rail, and the portion in contact, instead of being a line, is a parallelogram more or less irregular in outline. I measured these surfaces some years ago, under the driving wheels of locomotives, and found that they varied from 0.13 to 0.42 of a square inch in area, corresponding to pressures from 85.961 to 26.607 pounds per square inch, the diagrams having been published in the "Railroad Gazette" for April 21st, 1876.

It is an error, however, to assume that for car wheels this parallelogram is anything like one inch in length, transversely of the rail. This was probably arrived at by assuming that the portion of the rail kept bright by the trains, truly represents the length of contact. This bright portion, however, is not only kept so by the action of successive wheels.

many of them much worn, which strike various points on the rail, but is also largely the result of the attrition of the driving wheels of locomotives, which are but slightly coned in the flanged tires, and not all in the blank tires. It does not, therefore, give a true measure of the length of the parallelogram of contact. It is probable that for a new car wheel upon a new rail, it does not exceed $\frac{3}{8}$ of an inch in length, and in fact the bright streak left by the first few trains upon the Elevated Railroad in New York, now about ready for operation, does not exceed $\frac{1}{4}$ to $\frac{3}{8}$ of an inch across the face of the rail.

The error in the assumption of the length of this surface of contact, causes a corresponding error in the calculations of the resistance due to the coning of the wheels, which, instead of being about half a pound per ton on a straight line, is probably not more than $\frac{1}{5}$ to $\frac{1}{4}$ of a pound per ton, or materially less than the curve resistance for a single degree, while the curve resistance, say on a ten degree curve, would be about five pounds per ton.

The paper is so interesting and valuable that it is to be hoped that the author will pursue further his investigations, and give to the society a supplemental paper on the same subject.

Mr. Charles E. Emery.—Mathematical discussions are of great value in enabling the well-understood relations of simple physical phenomena to be grouped together to determine approximately questions of a higher order, and the resulting expressions in turn suggest the direction of investigations whereby the constants in the equations may be corrected, and the experiments thereby be comprehensively utilized.

The paper of Mr. Whinery under discussion is of great interest, and shows evidences of thought and careful preparation. In my opinion, however, he has omitted two elements of curve resistance and overestimated a third, while two other elements, separately treated in his paper, so modify each other that they should be jointly considered. The various modifications to some extent balance each other, but all are essential to a complete examination of the subject.

Both elements believed to be omitted affect principally the flange resistance. The paper discussed only the resistances of this kind arising from the fact that parallel axles in a truck cannot take radial positions on a curve. The wheels tend to roll in a tangent but by flange resistance are continually slipped transversely on the rails. (See § 6.) The paper separately estimates, § 5, the resistance due to slipping the wheels the distance due to the difference of length of the inner and outer rails, but

neglects to include the increased flange resistance caused by the longitudinal slip. The inward slipping due to the parallelism of the axles would occur if the wheels on the two ends of the axle could turn independently one of the other, but the flange resistance necessary to slip the wheels in the direction of the rail would be saved by the use of independent wheels, and should, therefore, be included in ordinary cases where the wheels are rigidly connected to the axle.

These considerations, however, lead us to the conclusion that it is erroneous to consider the longitudinal and transverse slipping separately.

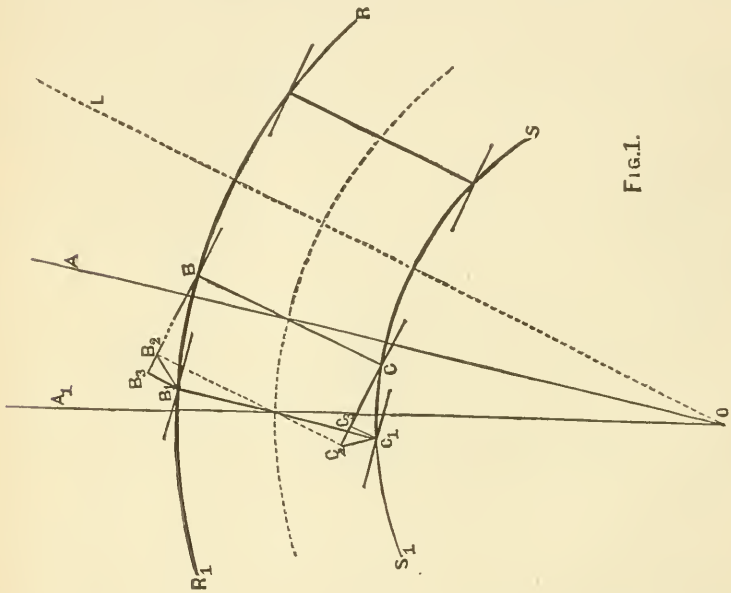

FIG. 1.

Referring to Fig. 1, let RR_1 and SS_1 represent curved rails; OA and OA_1 two radii of the curve, and BC and $B_1 C_1$ the positions of the leading axle of a truck corresponding to such radii, then it is evident that as the system moved through the angle at O, the wheels at B and C would tend to roll in parallel lines to the points B_2 and C_2, but would be forced to move to the positions B_1 and C_1. That is, B would be forced *inward* a distance $B_3 B_1$ and *forward* a distance $B_2 B_3$, so the actual slip would equal the diagonal $B_2 B_1$. At the same time C would be forced *inward* a distance $C_3\ C_1$, and *backward* a distance $C_2 C_3$, so the actual slip of the inside wheel would equal the diagonal $C_2 C_1$. Differences in the distribution of the weight will affect the relative amount of slip on the two rails,

but when the car is uniformly loaded on the two sides and the super-elevation of the outer rail, that due to the speed, the slip should be as per diagram. Corresponding modifications of Mr. Whinery's formula will be submitted when his paper is accessible in print.

In this connection it is suggested also, that probably formula (4), § 4, could also be included in the same expression, as the problem of twisting each wheel, or practically a short cylinder on the rail through a given angle, is much the same as slipping two connected wheels, or practically a long cylinder through the same angle.

The second element of resistance neglected is that required to turn the car through the angle from one tangent to the other. If we suppose a car body supported on a single truck, and propelled on a curve by force applied to the truck itself, the whole mass will develope the centrifugal force discussed in § 1 of the paper. The car body would not, however, change its angle in space, but remain in all positions on the curve parallel with its original position. (See Figure 2.) Under the conditions

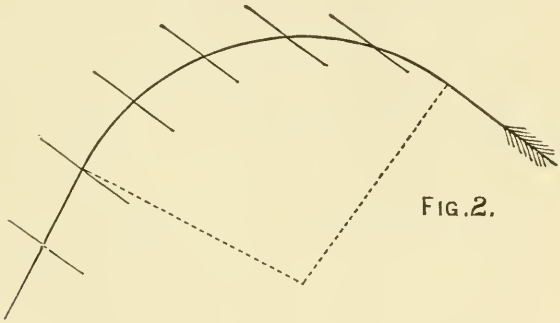

FIG. 2.

of practice, then, force must be applied to revolve the car body through the angle named. If the body be fast to the frame carrying the wheels, as in short cars, the angle of the whole mass must be changed on a centre passing through the rear axle, and the force required to make the change causes extra resistance on the flange of the outer leading wheel. In a car with two trucks each must be revolved by the leading wheels as before, but the car body will be turned by the leading truck, on the after truck as a centre. The leading truck of a locomotive makes high speed possible with increased safety and a reduction of resistance, as the mass is piloted around the curve and its angle changed by force applied well forward of the centre of gyration, in relation to the after rigid wheel base.

Similar advantages are obtained with our American double bogie cars. In cars with the body fast to the frame carrying the wheels, as in street cars, the front wheels generally fall inside the centre of gyration of the mass to be revolved, and with the corresponding loss of leverage the flange resistance is materially increased. The force required to turn the car is in any case evidently too important to be neglected.

I must disagree with the author that the tractive efforts transmitted from one car to another on a curve, are reduced at each car in the proportion of the cosine of the exterior angle of the funicular polygon, to radius. (See § 8.) It is simply the problem of deflecting a force as is done when a rope under strain is wound round a pulley; the train being practically a chain for transmitting power. A lateral force is developed in changing the direction represented approximately by the sine of the angle referred to (or) a fraction of the angle. (See equation 10.) But this force is not expended, except so far as it produces friction on the flanges and the shoulders of the axles.

In respect to coning the wheels, I would state that some years since, when riding at a high rate of speed on the Erie Railroad, I observed that the car ran from side to side of the track, bringing up with a jolt against the flanges. This was attributed at the time to coned wheels, and it is probable that slight curves and other causes were sufficient to start the car in a sidling movement, which the coning of the wheels maintained in accordance with the ordinary principles of vibration. The effect of insufficient elevation of the outer rail, is plainly observable on the Baltimore & Ohio Railroad. The track being regulated for coal traffic, in many places the cars of express trains are thrown violently against the outer rail, and rebounding, are thrown out again and again, producing very unpleasant sensations.

The contradictory results of experiments on curve resistance are probably due, in most cases, to changes of speed on the curve. While the speed is slacking, the dynamometer will show less strain than is due to the actual resistance; the reduction of the *vis viva* of the mass developing a propelling force; while, if the engine is worked harder, for the moment, the indications of the dynamometer will be in excess of the true curve resistance by an amount corresponding to the increase of speed. Some want of correspondence among results with the dynograph I could only explain in this way. No dynamometer experiments can be entirely reliable unless conducted in connection with a velocimeter, by means of

which either the speed may be regulated or proper corrections made afterward in the results. Marking the time at intervals on the dynamometer diagram or a sheet of paper, traversed by the train, is not sufficient. A continuous register of the velocity is necessary.*

Mr. Edmund Yardley.—Refinements in calculation to determine the elevation of the outer rail on curves seem to me rather unnecessary, since the element of speed in miles per hour which enters the formula cannot be assumed, but the proper elevation due to the average speed, all things considered, must be determined experimentally.

The following example, covering experience for a number of years may prove interesting. When an assistant-engineer on the Pennsylvania Railroad at Pittsburgh, in 1859, I gave one of the sub-division foremen, at his request, the figures for the elevation of his curves, merely copying from Henck's table the figures for 30 and 40 miles per hour. On my returning to the Pittsburgh Division, nine years afterwards, he told me that when he put up his curves to the figures given in the table for 30 miles, the trains ran around them to his perfect satisfaction. The figures were as follows: 1° $\frac{5}{8}$"; 2° 1$\frac{1}{4}$"; 3° 1$\frac{7}{8}$"; 4° 2$\frac{3}{8}$"; 5° 3", &c. His division was the first four miles east of Pittsburgh, the track there has a grade of about 52 feet per mile, and the curves, as I remember, were from 2° to 4°. As it was double track, and I understood him to say he used the same figures for both tracks, we must have had speeds here varying from 10 to 40 miles per hour.

While on this subject, let me suggest that answers to the following questions would be interesting:

1st. What is the true criterion for the proper elevation of a curve? Is it: 1st, that the train shall pass round with the greatest smoothness, or 2d, that both rails should wear equally? My opinion is, that the second is the correct one, the passage of the train being due to correct align-

* In the above connection, I will state that in testing the resistance of street cars recently, I found that the customary springing forward of the horses on approaching a curve entirely vitiated the results, and no satisfactory records could be obtained until the cars were tried on a sharp curve and steep grade, where a hard, steady pull was necessary. A practically uniform velocity of approach was obtained by stopping each car six feet before the beginning of the curve. The experiments appeared to show that the mean tractive effort required to propel a street car at a slow speed on the level, is 11.8 pounds per ton. Wheels 30 inches in diameter; journals 2$\frac{5}{8}$ × 6 inches, weight of car, empty, 4 500 pounds. The resistance on a level curve of 40 feet radius was for rigid wheels 53.57 pounds per ton of 2 000 pounds, and for independent wheels 34.03 pounds per ton, making the saving in total resistance, due to the use of the latter, 36.48 per cent. Deducting from each 11.8 pounds the resistance on a straight line, the saving in curve resistance proper was found to be 46.78 per cent.

ment. The foreman above spoken of adopted the first, so that I am in doubt whether to be satisfied with his conclusion or not.

2d. Can you elevate the outer rail sufficiently to keep the flanges of the wheels away from it, so that they will not cut (I* never had it occur, but I am informed that it has happened). If so, what were the elevation and other conditions of the case; were the wheels excessively coned?

Mr. Edward P. North.—I wish to call attention to the fact that though a single pair of wheels would go around a 3° curve without flange friction, in effect two pairs of wheels are placed in a truck with their axles rigidly parallel, and in that case the system will, on a level surface, advance in a right line, even if both the wheels on one side of the truck are of greater diameter than those on the other side. From which it would seem that aside from the necessities of manufacture and affording a margin for wear, there are no advantages to be derived from coning the wheels,

Mr. Charles L. McAlpine.—Petersburg and Richmond, Virginia, fell into the hands of the Federal troops near the close of the war.

The base of the latter for many months had been at City Point on the James River.

Early one morning imperative orders were received to run the trains of the United States Military Railways into Petersburg with the least possible delay.

This was done by noon of the same day, under circumstances that would be most interesting, but foreign to the subject under discussion.

This order was followed up by another; that railroad communication with Richmond, should be effected at once.

The railroad bridge at Petersburg, over the Appomattox, had been burned. No connection at that place had ever been made in peace times, and the first examinations showed that heavy excavations. &c., requiring *time* (for which the department never made allowance), *must* be made, before any reasonable connection with the Richmond line could be effected.

This drove the engineer in charge into the apparently inadmissable curve adopted.

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* My experience led me to think it never would occur, since the slow freight trains up the mountain cut away the outer rail on the curves at Kittaning Point.

Contrary to the advice of trackman and bridge builders, a sharp curve was laid out, of more than one hundred degrees, with a radius of fifty feet, on what was to become the main line.

The curve was on trestle work, and the outside posts were framed eight inches longer than the inner ones. The ties were of sound white pine, three inches in thickness, and the rails were double spiked.

Two guard rails were used, also double spiked.

The locomotive engineers generally condemned the bridge and curve at first sight after completion, and a strong prejudice was created against it. But the writer selected the worst curve following engine in the service, the "Government," and ordered her to make the first trial.

Walking backwards, and in front, as this engine slowly made its way, it was easy to perceive her action on this sharp curve.

A little pressure on the outer rail, seemed to drive the wheels (both of the trucks and drivers) down on to the inner rail, and demonstrated practically what had been intended, that the trains must be passed through the curve at greater speed.

Thereafter, when the locomotive men became accustomed to the curve the speed through it was usually from eight to ten miles an hour.

A very large traffic passed over this curve for months afterwards, supplying the armies of occupation in Richmond, and at other points to the southward, and no accident or trouble whatever was experienced at the place in question.

Mr. F. Collingwood.—The question of friction on curves naturally leads to the discussion of the various methods proposed for obviating the difficulty, and in this connection I wish to speak of some recent experience at the East River Bridge. The tramway used for transporting material from the pier on the East River to the anchorage and approach has curves of twenty-nine feet, thirty-four feet, forty-six feet and sixty feet radius, and a gauge of four feet eight and a half inches.

In designing the cars, the axles were made rigid, and wheels loose; and as they are for carrying heavy loads, there are no springs.

While the cars are new, they work very well by giving a litle end play to the wheels; but after the holes in the hubs become worn, it is only by giving great freedom in the gauge, and at "points," that we can keep them on the track.

I am satisfied that a much better arrangement would be to have the wheels fixed, and divide the axles in the middle, using either long

sheaves to connect them, or central boxes. This would no doubt lessen the friction materially and be free from the great trouble caused by wear in the hubs.

Another difficulty experienced is the passage of reverse curves, where there is no tangent between them. With such sharp curves, it is absolutely essential to elevate the outer rail, and the result is that some one of the wheels is lifted free from the track as the car passes from one curve to the other. In the management of the cars, a great deal depends upon the skill of the driver in the proper use of the brake, and keeping the proper line of draft, to overcome the tendency to derailment.

Mr. William H. Paine.—In an examination of certain mechanical appliances, intended to obviate the rigid axle, I have observed that the amount of lost motion was so great that a really contrary motion or resistance was the result.

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CLX.

(Vol. VII.—May, 1878.)

ON THE CAUSE OF THE MAXIMUM VELOCITY OF WATER FLOWING IN OPEN CHANNELS BEING BELOW THE SURFACE.

By JAMES B. FRANCIS, C. E., Member of the Society.

Hydraulic engineers have been very unwilling to admit that, generally, in open channels the greatest velocity is not at the surface, but at some distance below; the fact is, however, now too well established by numerous experiments to be any longer doubtful. Some have attributed it to the resistance of the air, and this, undoubtedly, must frequently tend to produce such an effect, more particularly when the wind is strongly opposed to the current; but it has been observed that the greatest velocity is at some distance below the surface when the wind is in the same direction as the current, when its tendency must be to quicken the surface velocity.

At Lowell, Massachusetts, the water drawn from the canals by the manufacturing companies, is in several cases, gauged in what are there

called *measuring flumes.* These are constructed in parts of the canals where the section is rectangular and the alignment as free from bends or other irregularities as practicable; they are simply linings of the bottom and sides with smooth planking, retaining the direction, and, as nearly as practicable, the dimensions and form of the canal. The velocity of the flow in these flumes is ascertained by means of tin tubes, loaded at one end with lead, so as to sink nearly to the bottom. It is observed that there is a continual change in the velocity in all parts of these channels, although there may be no sensible change in the volume of water flowing, and, consequently, none in the *mean* velocity; this must result from a continual change in the position of the currents moving with different velocities.

The contact of the water with the planking forming the sides of the flume retards the velocity of the adjacent parts of the stream; parts more distant from the sides move more rapidly; this difference in velocity tends to produce eddies in which the water is, of course, moving in all directions. One effect of this, I think, is to allow some of the quicker moving currents to penetrate those moving more slowly, and to detach masses of water from the slow currents, and force them further from the sides, where they become the slower currents among those moving quicker.

To ascertain the velocity in different parts of the width of the flume, the tubes are put into the water, and, when in a vertical position, are abandoned to the current, and the time of their passage between two cross sections observed; from this their mean velocity is obtained. To test this method of gauging the flow of water, experiments were made in a flume fitted up for the purpose, in which the usual causes of irregular motions were reduced to a minimum. The arrangements for ascertaining the velocities of the tubes by means of an electric telegraph and a marine chronometer, operated by skillful observers, also reduced the errors of observation to a minimum.

The variations in the velocity in particular parts of the flume when there was no sensible change in the mean velocity, were, however, very marked. This is plainly shown by the diagrams in Plate XVII., Lowell Hydraulic Experiments,* in which the velocities in several observations are represented by the ordinates of the small circles and the mean velocity by the corresponding ordinate of the full line. The

* Lowell Hydraulic Experiments, 2d Edition. D. Van Nostrand. New York. 1868.

variations in the ordinates of the small circles for the same abscissa, indicate the changes of velocity at that part of the flume, which result from the changes in the currents.

In the diagram of Experiment 1 the variations extend from 8.57 per cent. above the mean to 11.40 per cent. below ; the average variation in thirty observations in different parts of the width of the flume being about 3.12 per cent. These variations are deduced from the mean velocities of the tubes through a course of seventy feet ; the variations in some parts of the course must have largely exceeded these averages. The variations in velocity just described are deduced from exact observations in different parts of the width of the stream ; similar, and probably greater, variations must occur in different parts of the depth, resulting from the same cause, namely, the constant interchange in the position of the currents moving with different velocities ; we have not, however, the observations at hand to verify it, and they would not be so readily made ; but we may safely infer from those already described, that they do exist. In rectangular channels in which the depth is less than half the width, the retarding effect of the bottom must exceed that of the sides, and the eddies and other irregular motions resulting, must be greater in the same ratio, and the effect previously described, of the quicker currents penetrating those moving slower, and detaching, and, in this case, forcing upwards, masses of the slow moving water, must occur to a greater extent than results from the retardation caused by the sides.

These slower-moving masses would be carried along by the quicker moving water, and would soon, but not at once, acquire the same velocity; many of these would reach the surface before fully acquiring the normal velocity, where their living force, in a vertical direction, would be expended in spreading out laterally, and where the force was considerable, in producing the boils so frequently seen, particularly in natural water courses.

The constant recurrence of the same phenomena, must cause an accumulation of water at and near the surface, moving with a mean velocity somewhat less than the mean velocity of the water at some distance below the surface. If these views are correct, there must be a constant movement of water from near the bottom of an open channel of running water to the surface; to test this, the following experiments were made in the canals at Lowell, supplying the manufacturing establishments with water for motive power.

EXPERIMENTS IN THE WESTERN CANAL, JULY 6, 1867.

These experiments were made in a straight reach of the canal, about 1 200 feet in length, in which the section was nearly uniform, viz.: about 20 feet wide at bottom, 50 feet wide at the surface of the water, and about 10 feet deep. The velocity of the water in the middle of the canal at the surface, was about 3.4 feet per second. No water is added to or abstracted from the canal in this reach. This canal is excavated partly in gravel and partly in rock; the bottom of the canal is now all gravel, with a few small stones which have rolled in from the sides; a portion of the sloping sides are rock; much the longest portion, however, in the part of the reach where the experiments were made, is gravel, having only moderate inequalities of surface. A large flat-bottomed boat, drawing a few inches of water, was moored about 500 feet from the up-stream end of the reach. On one side of the boat, in the middle of the canal, a lead pipe of two inches interior diameter, attached to a small post, was placed vertically, with the lower end bent, so that the centre of the lower orifice was about five inches above the bottom of the canal, and pointed down stream, in the direction of the current. The pipe extended about four feet above the surface of the water, and was connected, at its upper end, to a tub which contained about 3.1 cubic feet of whitewash. In the bottom of the tub was an orifice, communicating with the pipe, which could be closed by a plug.

At the commencement of an experiment the tub was nearly filled with whitewash, at a given signal the plug was withdrawn, the whitewash was discharged at the lower orifice in about 22″; observers were stationed on the banks below, to note the appearance of the whitewash at the surface. The water was nearly clear, permitting the banks to be seen at a depth of three or four feet.

Eight trials were made, in which the whitewash appeared at, or very near, the surface, at distances from the lower orifice in the pipe varying from about 100 to 175 feet; the mean of the distances, as recorded, being 129 feet.

EXPERIMENTS IN THE NORTHERN CANAL, JULY 25, 1867.

These experiments were made in a reach of the canal of uniform section, straight, free from obstructions, and about 1 100 feet in length, in which no water was added or abstracted. The canal has walled sides, and is 97 feet wide at the bottom and 103 feet at the surface of the water, which is 16.5 feet in depth; a small portion of the excavation is in rock; the bottom of the canal is nearly all gravel, with irregularities of eleva-

tion of only a few inches. The sides are walled, except at a few points where the rock projects, in no place, however, more than 1.5 feet from the line of the face of the wall. The velocity of the water in the middle of the canal, at the surface, was about 2.2 feet per second.

An examination of the bottom of the canal was made a few days before the experiments were made, the water having been drawn off; at this time all the stones on the bottom exceeding about three inches in their smallest dimension, were removed from the central parts of the canal and placed near the sides. The flat-bottomed boat, used in the western canal, was moored near the middle of the reach, and arrangements made for discharging whitewash near the bottom of the canal, similar to those in the western canal, previously described, the pipe being of wood, four inches square inside, to the top of which was attached a tub holding 5.56 cubic feet of whitewash, which was discharged on the removal of a plug, in about four seconds.

Five trials were made, in which the whitewash appeared at, or near, the surface, at distances varying from about 300 to 500 feet from the point at which it was discharged into the canal. The sides of the canal are but little above the level of the surface, which, combined with the width of the canal, did not permit the observations to be made so definitely as in the western canal, where the banks are higher and the canal about one-half the width; about 530 feet below the point where the whitewash was discharged a bridge crosses the canal, from which the whitewash was seen at or very near the surface on the up-stream side of the bridge, in each of the five trials. In one trial only the whitewash was observed at about 300 feet from the point where it was discharged. In one trial the whitewash was first seen near the bridge in 4′ 55″ after it was discharged, and masses of it continued to be seen at short intervals for about 1′ 30″. In another trial it was first seen near the bridge in 4′ 58″ after it was discharged and continued to be seen for about 1′ 20″. The whitewash, as it appeared near the surface, approaching the bridge, was much diffused, but quite distinct, and in masses resembling the globular masses of smoke discharged from chimneys, at some distance from the tops of the chimneys.

From these experiments it appears that the water at the bottom of the streams came to the surface, at distances varying from about ten to thirty times the depth, the shorter distances being in the canal of the least depth and most uneven bed.

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CLXI.

(Vol. VII.—May, 1878.)

THE FLOW OF WATER IN PIPES UNDER PRESSURE.

By CHARLES G. DARRACH, C. E., Member of the Society.

In the well known equation for the flow of water in pipes,

$$h'' = \frac{CLmv^2}{2gS} \text{ or } h'' = \frac{4mLv^2}{2gd}\,*$$

the value of "m" has been given by various experimenters for straight clean pipes of different diameters, and for different velocities.

The following tables have been deduced from experiments on the pumping mains of the Philadelphia Water Works, and show the effect produced by abrupt bends, check valves and foul pipe.

The temperature of the water was about 62°, and its weight has been considered as 62.338 lbs. per cubic foot.

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* h'' = friction head in feet.
v = velocity of flow in feet per second.
g = 32 feet.
m = coefficient of flow.
$\frac{S}{C} = \frac{d}{4}$ = hydraulic mean radius in feet.
C = contour of pipe in feet.
S = sectional area.
L = length of pipe in feet.
d = diameter of pipe in feet.

Experiment No. 1.—May 23, 1878.

Belmont Works—30-in. main, laid in 1869. Engine, "Worthington." 5 per cent. deducted for slip. One curve, of short radius. Gauge on main outside check valve.

$$m = \frac{2gh''d}{4Lv^2}$$

30 inch Main, laid Nine Years.

Engine.		Pipe.			Head.					
Revolutions per Minute.	Cubic Feet per Minute.	Diam.	Area.	Velocity in Feet per Second.	Gauge.	Total Head.	Static Head.	Friction $H-h$.	Length of Pipe.	m.
		d.	S.	v.	lbs.	H.	h.	h''	Ft.	
0				0	82.25	190	190	0.		
8				1.070	84.00	194.04	"	4.04		.03208
9	357.3			1.205	84.25		"	4.62		.02900
10	397.0			1.340	84.50	195.2	"	5.20		.02633
11	436.7			1.475	84.75		"	5.78		.02416
12	476.4	30″ = 2½ ft.	4.91 sq. ft.	1.610	85.00	196.35	"	6.35	4,400	.02229
13	516.1			1.745	85.25		"	6.93		.02069
14	555.8			1.880	85.50	197.51	"	7.51		.01931
15	595.5			2.015	85.75		"	8.09		.01811
16	635.2			2.150	86.00	198.66	"	8.66		.01703
17				2.285	86.25		"	9.24		.01609

Experiment No. 2.—June 1, 1878.

Spring Garden Works—36-in. main, laid 1871. Engine, "Simpson." All curves, 25 feet radius ; no checks.

$$m = \frac{2gh''d}{4Lv^2}$$

36-inch Main, Seven Years Old.

Engine.		Pipe.		Velocity in Feet per Second.	Head.				Length.	m.
Revolutions per Minute.	Cubic Feet per Minute.	Diam.	Area.		Gauge.	Total Head.	Static Head.	Friction Head $H-h$.		
		d.	S.	v.	lbs.	H.	h.	h''	Ft.	
					43.25	100.				
10	670			1.58	44.78	103.45		3.45		.01791
11	737	36″=3 ft.	7.07 sq. ft.	1.74	45.03	104.03	100 ft.	4.03	3700	.01718
12	804			1.89				4.61		.01673
13	871			2.05				5.19		.01601
14				2.21				5.77		.01536
15				2.37				6.35		.01466

Experiment No. 3.—June 1, 1878.

Roxborough Works. 20″ main—laid in 1867. Engine—"Worthington." 5 per cent. deducted for slip. One quarter turn at basin. Gauge on pump.

$$m = \frac{2gh''d}{4\,Lv^2}$$

20-inch Main, Laid Eleven Years.

Engine.		Pipe.		Velocity in Feet per Second.	Head.				Length of Pipe.	m.
Revolutions per Minute.	Cubic Feet per Minute.	Diam.	Area.		Gauge.	Total Head.	Static Head.	Friction $H-h$.		
		d.	S.	v.	lbs.	H.	h.	h''.	Ft.	
0					135.5	313.0	3130	0		
9				2.71	142.75		"	16.75		.01419
10	394			3.01	144.	332.64	"	19.64		.01318
11	433.4			3.31	145.25		"	22.52		.01269
12	472.8	20 ins. = $1\frac{2}{3}$ feet.	2.18	3.61	146.50	338.42	"	25.42	4320	.01204
13	512.2			3.91	147.75		"	28.31		.01147
14	551.6			4.21	149.0	344.19	"	31.19		.01093
15	591.0			4.51	150.25		"	34.08		.01033
16	630.4			4.81	151.5		"	36.96		.00986
				5.11	152.75		"	39.84		.00941

EXPERIMENT No. 4.—JUNE 5, 1878.

Delaware Works. 36″ main. Laid in 1871. Engine—"Worthington." 5 per cent. deduction for slip. Gauge on stand pipe. Curves in pipe made with 25 feet radius, except at the basin where 90° are made with a T pipe.

$$m = \frac{2gh''d}{4\,Lv^2}$$

36-INCH MAIN, LAID SEVEN YEARS.

Engine.		Pipe.			Head.					
Revolutions per Minute.	Cubic Feet per minute.	Diam.	Area.	Velocity in Feet per Second.	Gauge.	Total Head.	Static Head.	Friction Head $H-h$.	Length of Pipe.	m.
		d.	S.	v.	lbs.	H.	h.	h''	Ft.	
0					51.25	118.4	118.4	0		
9	423			1.000				13.00		.05033
10	470			1.111^1				13.28		.04170
11	517			1.222^2				13.57		.03506
12	564	36 ins. = 3 feet.	7.07 square feet.	$1\frac{1}{3}$	57.25	132.25		13.86	12.400	.03021
13	611			1.444^4				14.15		.02626
14	658			1.555^5	57.50	132.83		14.44		.02314
15	705			$1\frac{2}{3}$				14.73		.02055
16	852			1.777^7	57.75	133.40		15.01		.01847
17				1.888^8				15.30		.01667
18				2.000				15.59		.01509

Experiment No. 5.—June 6, 1878.

Frankford Works. 30″ main laid 1876. Engine "Cramp." 5 per cent. deducted for slip. Grade undulating.

Curves of 25 feet radius.

4 check valves on main.

Area of openings in check, 750 sq. inches.

Weight of valve, 320 lbs. in 1 check.

Gauge on air vessel. Weight of 4 checks. 1 280 lbs.

$$m = \frac{2gh''d}{4\,Lv^2}$$

30-inch Main Two Years old.

Engine.		Pipe.			Head.					
Revolutions per Minute.	Cubic Feet per Minute.	Diam.	Area.	Velocity in Feet per Second.	Gauge.	Total Head.	Static Head.	Friction Head $H-h$.	Length of Pipe.	m.
		d	S.	v.	lbs.	H.	h.	h''	Ft.	
0		30 ins. = 2.5 feet.	4.91 square feet.			167.3	167.3		20,210	
10	433			1.47				10.43		.00947
11	476.3			1.62	77.5	179.03		11.73		.00885
12	519.6			1.76	78.+			13.03		.00833
13	562.9			1.91	78½+			14.33		.00777
14	606.2			2.06	79¼−			15.63		.00726
15	649.5			2.20	79.75	184.23		16.93		.00692
16	692.8			2.35	80¼+			18.23		.00653
17	736.1			2.50	80¾+			19.53		.00618
18	779.4			2.64	81½−			20.83		.00591
19	822.7			2.79	82.	189.42		22.12		.00562
20	866.0			2.94	82½+			23.42		.00534
21	909.3			3.68	83⅛+			24.72		.00516
22	952.6			3.23	83.7			26.02		.00493

Deduction From Experiment No. 5.

Frankford 30″ Main.—The check-valves in the main produce a pressure of 1.8 lbs. per square inch, which is equal to a head of 4.16 feet. This amount deducted from the friction head in Table No. 5 gives the corrected friction head:

$$m = \frac{2gh''d}{4Lv^2}$$

30-inch Main. Two Years Old.

Engine.		Pipe.			Head.					
Revolutions per Minute.	Cubic Feet per Minute.	Diam.	Area.	Velocity in Feet per Second.	Gauge.	Total Head.	Static Head.	Friction Head. $H-h$.	Length.	m.
		d.	S.	v.	lbs.	H.	h.	h''.	Feet.	
10	433			1.47		173.57	167.3	6.27		.00575
11	476.3			1.62	75.7			7.57		.00571
12	519.6			1.76				8.87		.00561
13	562.9			1.91				10.17		.00552
14	606.2			2.06				11.47		.00535
15	649.5	30″ = 2.5 ft.	4.91 sq. ft.	2.20	77.95	180.07		12.77	20,200	.00522
16	692.8			2.35				14.07		.00503
17	736.1			2.50				15.37		.00487
18	779.4			2.64				16.67		.00473
19	822.7			2.79	80.2	185.26		17.96		.00452
20	866.0			2.94				19.26		.00441
21	909.3			3.08				20.56		.00429
22	952.6			3.23				21.86		.00415

Experiment No. 6.—June 11, 1878.

Roxborough 30-inch Main laid 1878.—Engine, "Worthington." 5 per cent. deducted for slip. One quarter turn. All other turns made with curve pipe of 25 feet radius. Two check-valves on main.

The weight of the valves, 1.3 lbs. per square inch, has been deducted from the observed pressure on the gauge.

$$m = \frac{2gh''d}{4Lv^2}$$

30-inch Main. New.

Engine.		Pipe.		Velocity in Feet per Second.	Head.				Length.	m.
Revolutions per Minute.	Cubic Feet per Minute.	Diam.	Area.		Gauge.	Total Head.	Static Head.	Friction Head. $H-h$.		
		d.	S.	v^2.	lbs.	H.	h.	h''.	Feet.	
0					140.33	324.16		0		
12	472.8	30-inches = 2.5 ft.	4.91 sq. ft.	1.60	141.0	325.71	324.16	1.55	4000	.00606
14	512.2			1.74				1.83		.00604
14	551.6			1.87	141.25	326.27		2.11		.00603
15	591.0			2.00				2.40		.00600
16	630.4			2 14	141.5	326.84		2.68		.00590

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(Vol. VII.—May, 1878.)

DISCUSSIONS ON

THE CAUSE OF THE MAXIMUM VELOCITY OF WATER FLOWING IN OPEN CHANNELS BEING BELOW THE SURFACE, AND ALSO ON THE FLOW OF WATER IN PIPES UNDER PRESSURE.*

By THEODORE G. ELLIS, CHARLES E. EMERY, CLEMENS HERSCHEL, DE VOLSON WOOD and J. T. FANNING.

THEODORE G. ELLIS. I think Mr. Francis is undoubtedly right in saying that it is not the effect of wind or the resistance of the air upon the surface of the water that causes the retardation, as numerous experiments have proved that when the wind is blowing down stream the water will still be retarded at the surface. It is likewise true that the currents are all the time being interlocked and mixed. The thread of greatest velocity is never long in the same place; it is constantly swaying from side to side and rising and falling. But I cannot readily understand Mr. Francis' idea of the coming up of more slowly moving masses of matter from the resistance of the bottom—in the shape of a curve. From observations upon the Mississippi and other rivers it would appear that if the resistance comes from the bottom and acts

* Referring to Papers CLX and CLXI, Vol. VII (May, 1878).

directly upwards, every particle of water that moves from the bottom must pass through the thread of greatest velocity. I do not see any good reason why the greatest velocity of this thread should not be given to every particle of water that passes up through it. If the retardation is communicated from the bottom to the top, it must be in curves, so that the rising water must have a retrograde movement as it passes above the thread of greatest velocity before it gets to the top. It cannot, it seems to me, be transmitted directly.

It has troubled hydraulic engineers a great deal to know what causes this resistance at the surface, and I will confess that I am unable to solve that problem, although there is some reason, in my opinion, to believe that it is caused by the resistance of the banks and of the bottom near the banks. We find that in very wide and shallow streams the velocity approaches very near the surface, while in deep streams, with steep banks, the thread of greatest velocity is carried lower down. As instances of this there are the experiments of Mr. Révy, on a section five miles wide with a depth of forty or fifty feet, in which he observes the current and finds the greatest velocity at the surface; and in the experiments of Darcy and Bazin, as published in their work, we find that in rectangular channels we have the greatest velocity nearly in the middle of the section: the retardation at the middle of the surface seems to be communicated in some way from the sides, the water near the sides being so much slower, would seem, being near the surface, to hold it back near the middle. It seems to me that this offers the only plausible solution of the problem. It is found that in very wide rivers we have the greatest velocity near the surface, and in rivers with contracted and steep, perpendicular banks, the thread of greatest velocity is carried down almost to the middle. That fact would seem to verify this theory.

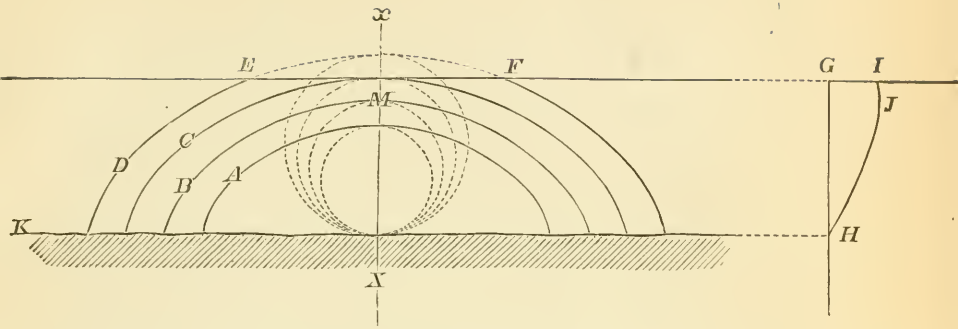
There is another peculiarity about the curve of vertical velocities to which my attention was first called by Gen. Warren of the U. S. Engineer Corps. The resulting curve from a large number of experiments always has a depression just below the middle, almost making it a straight line. It is flattened so as to make the general curve to near the bottom a parabola. In trying experiments nearer the bottom than were tried on the Mississippi, we find that the curve recedes very rapidly. There is a flat place left between the bottom and middle. This is a feature of all the vertical curves that I have observed, and it is quite marked in some of them. So that it seems that there are really two

systems of forces acting, one to produce the curve at the bottom and another to produce the curve at the top.

In reference to the flow of water in channels, it will require a great deal more observation than has yet been given to it to find laws that will govern any number of streams. Formulæ that are applicable to the Mississippi and large rivers do not appear to be applicable to small rivers, and formulæ that are applicable to small streams are not applicable to large ones.

Charles E. Emery.—While listening to the paper of Mr. Francis and the remarks of Gen. Ellis, on this subject, it has occurred to me that the phenomena can be explained by considering that the combined vertical and progressive movements of the water resemble, on a large scale, the eddy resistance caused by the passage of fluid along surfaces in general. It has been demonstrated that each particle of water in a wave moves in a circle, and that the several particles following each other in order cause the successive crests and hollows together with an appearance of progression which does not actually exist. In eddy resistance, however, the particles move in a circle which has a progressive movement, so that the path of each particle in space is in a cycloid or a modification of the same.

To apply this principle to the motion of water in open channels, we have but to consider that the particles of water are continually receiving impulses upward (or normal to the bed of the stream) by deflection of the current from projections on the bottom or the fluid retarded thereby. The upward motion combines with the progressive movement of the current, but the particles continue to rise until stopped by forces opposite and equal to the original ones. Such opposite or downward forces result from the necessity of continually re-supplying the water projected upward. The path moved through by each particle should, therefore, resemble in its general features a cycloid,--at least so far as repetition of the curve is concerned,—though, perhaps each branch may be modified or distorted so, for instance, as to resemble the path of a projecticle. The distances above the bottom reached by the different particles would vary with the intensity of the deflecting forces, so that motion should result in a number of somewhat similar curves of different amplitude with their ascending and descending portions continuously crossing each other.



Representing the approximate paths of a few particles by the cycloidal curves *A B C D*, the ordinates will correspond to the variations in velocity. The reduced velocity of the surface may be accounted for by the fact that the upward impulse of some particles will be sufficient to carry the corresponding curve above the surface *O*, *G*, of the stream, when, necessarily, such particles spread out on the surface before attaining the maximum velocity at *x*. At some point below the surface, *M* for instance, the curves are uninterrupted, and the maximum velocity of the section is obtained. Representing the velocity at different heights by the ordinates of a curve, *I H*, measured from a vertical *G H*, it should be expected, from the above considerations, that the maximum would show below the surface at about *J*, as has been found practically and stated by the previous speakers. It is evident, also, that as the bed of the stream is deepened and approximates more nearly a semi-cylinder, the several curves normal to the surface of the bed should unite to raise the maximum velocity nearer to the surface, as has been stated by Gen. Ellis.

Clemens Herschel.—This touches upon a subject that forms a familiar theme of study with me, and has formed one for many years. And perhaps it will be well if I take the occasion to make what I shall call an appeal to the engineers present that they give us some better data upon this subject than we have yet been able to obtain. I should like to have this element introduced into this investigation—the element of

simultaneous observations. When we speak of a velocity curve—a curve of any shape you please—the one drawn on the black board or any other, and of any point on that curve—plotted as any intelligent engineer would plot a curve, the method which was followed to get that point or curve was this : the engineer put an instrument (of whatever sort you please), at that point to-day, at such an hour and minute, and he put it there ten minutes afterwards, and perhaps half an hour afterwards, and perhaps a week afterwards, and, from a great many times doing this, he says that in that cross section, and for that point, the average is there ; and then, during a different series of times the same thing is done in another place and the result given is that the average is *that*. Now, I have been so fortunate as to have done a good deal of work in an establishment that we shall visit by and by, where this principle of *simultaneous observation* has been carried on for a great many years, and has produced results of great value in hydraulic engineering. And it seems to me that if this same principle of simultaneous observation be applied here, it will produce equally novel and valuable results. I hope some engineer, who is so situated that he can do it, will carry out the suggestion. I want him to use a vertical wire or rod, or something of that sort, put down in the river, and I want half a dozen or more current meters put on that wire and connected with registers at the surface, by the use of electricity, so that the record of them all can be read simultaneously, and I want that record kept so that we can avail ourselves of it during the continuance of any reasonable length of time. I want these meters strung along at different depths and also at different places transversely, and I think that with a series of such observations we shall very soon arrive at that state of knowledge which we all are so much wishing for, and upon which alone safe theories could be founded.

De Volson Wood.—The remarks made by Mr. Francis in regard to the intermingling of the threads of water—perhaps I might say the particles of water—I think will commend themselves with some force to all of us. I will not presume to give a satisfactory reason for the thread of maximum velocity being at any particular point below the surface. But I will venture to make a suggestion ; I would not presume to make any statement in regard to it which would be construed into a theory, because so many others have thought upon the same subject before. It is said that particles from the bed of a stream work their

way up, so to speak, to the surface, and it is evident that if that takes place the particles at the surface find their way down to the bed. Now, we know that when a particle is acted upon by gravity, and is free to move, the acceleration of the velocity increases as the particle descends, and it seems to me that there may be some force in the presentation of it in this case. Admit that the particles ascend. They begin with a very slow velocity, and are constantly coming in contact with those which have a greater velocity, and these act upon each other, the slower retarding the faster, and the faster urging on the slower; and this conflict goes on until a condition of equipoise is reached. If that be the only operation, we must necessarily conclude, I think, that the maximum velocity would be at the surface. But those particles which have now reached the surface, must find their way back to the bottom again, and when they descend they will be retarded by passing the particles below, but accelerated by gravity, and from these causes may gain a point of maximum velocity somewhat below the surface. I do not see any particular force in the suggestion that these particles may move in cycloidal arcs, for I think it is extremely doubtful if they do. The subject of vortex motion has been raised in the question, and perhaps many of my hearers know quite as well as I, or even better, that Professor Reynolds, of Manchester, England, made some experiments some two years since, in regard to vortex motion of water in a trough, by introducing some colored matter into the water, by means of which he could see the peculiar motions which took place. A rapid circular motion of small portions of the liquid was produced, which passed rapidly the length of the trough without apparently disturbing the surrounding water. This motion is sometimes seen in the whirling motion of the ring of smoke as it ascends from a pipe or cigar, and passes through the air without involving that which lies about it. We also see that the small whirlpools in streams move rapidly through the water without disturbing the surrounding water. Now, when we recognize the fact that these complex motions do exist in flowing streams, I think it is not strange that a formula deduced from the flowage of one stream will not apply to others.

This brings to mind a remark that I have often made in regard to hydraulic engineers. There appears to be a peculiar satisfaction with them in discarding all that has been done before, and find fault with all their predecessors, and especially with those who have written on the

subject. The latest theorist believes that he has passed over and beyond the errors of those who preceded him. At least it appears as though the subject had not been, and perhaps cannot be, reduced to that exact scientific certainty which will prevent other investigators from modifying existing formulæ. The varied circumstances under which we see bodies of flowing water—in deep streams, narrow streams, large streams, and streams of all degrees of velocity—makes it quite evident that we cannot expect to arrive at a certain mathematical law. It is one of those subjects which seem to be beyond the grasp of pure analysis, and, consequently, is necessarily left to the hands of the experimenter. Everything which promotes accuracy of observation tends towards a more correct solution of the problem. Hence, Mr. Herschel's remark in regard to simultaneous observations was a very valuable one, and ought to be carried out. I suppose we can hardly doubt that the curve of velocity noted by Gen. Ellis and Mr. Francis is sufficiently accurate to establish the fact that the maximum velocity is generally greater at a point somewhat below the surface than at the surface. It is a matter that we would like to explain on theoretical grounds. But let us have the facts first, then the theory.

Charles E. Emery.—The remarks of the last speaker, that "the water may move in cycloidal curves, but that it is doubtful if it does," are hardly warranted in view of investigations that have already been made on the general subject. I call to mind, particularly, that the skin resistance of vessels has been satisfactorily explained on the hypothesis that the water rolls in circles on the surface as the vessel progresses, so, evidently, the motion of each particle is in a cycloid. The conditions in the case under consideration are entirely similar. It only requires that the deflecting forces be sufficient to cause the particles in due time to reach the surface, when, as has been shown, the various interesting phenomena described by former speakers are readily accounted for.

J. T. Fanning.—I had not expected to say anything upon this topic.* It is one very closely connected with what Mr. Francis and others have been discussing. As Mr. Darrach has presented the subject, it relates to the flow of water *under pressure*, while, as presented by Mr. Francis, it relates to the flow of water with a *free surface*, as in a stream or canal, and to the resulting currents.

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* Referring to Paper CLXI, Vol. VII (May, 1878).

If we consider the motion in this channel, sketched here upon the black board, which has, say sixteen feet depth, as that of a body of molecules of water, and think of the depth as in molecules, a thousand or more millions of molecules in depth, all of which move individually, and move past and between each other with very little friction, then, perhaps, we can more clearly understand the movement of the water currents or molecule groups.

Now, for instance, we will suppose that the minute individual particles of water in this channel are moving forward with a velocity relatively due to the sine of the angle of inclination of the water surface; thus, if there is one foot inclination in a mile, then there is a velocity which all these particles tend to take which is due to that inclination.

As these particles move forward they encounter obstructions, like, for example, this piece of rock sketched on the bed of the stream, then these particles that come in contact (and the group immediately surrounding them) are deflected. A different direction is given to them from that which they tended to take flowing under the influence of gravity, and the deflected group of particles passes through and between the particles moving in the first direction. Consequently, having taken a new direction, and having their progress checked by reaction from the obstruction, their *onward* progress is less than that of the main body of water, and the *mean* velocity of the whole body is reduced. Also, if the deflected group of particles passes up through the main body and reaches the surface, it is there unable to continue in the new direction, and is again deflected in part with a spreading movement towards the sides of the channel, with a further loss of onward velocity.

Considering the motion of the particles in this manner, we can readily understand how the current changes its velocity in certain parts, at the bottom, at the sides, and at the surface, as is demonstrated by experiment.

Those groups of particles near the bottom and sides of the channel are deflected frequently. Even though the channel is smoothly paved with brick, a portion of the moving particles meets obstructions at the edges of the paving, and are deflected upward from the bottom and inward from the sides, and thus lose their onward velocity that they tend to take from gravity in the general direction.

Now, in the cases of water flowing in pipes, there are projections on the sides of the pipes that influence and retard the *onward* motion of the particles.

We cannot so readily observe the influences of obstructions in pipes as in channels, but Mr. Darrach has given us some very valuable facts relating to them, in his columns of *co-efficients*, which are the measures of the influences of those obstructions.

If there are in the pipes any incrustations, or if the pipe castings are not smooth (and, in the ordinary cases, they are very far from being smooth—with the microscope they appear very rough) thousands and tens of thousands of these molecules or particles of water strike the little projectiles that are scarcely visible to the naked eye, and lose, by a serious of reactions and deflections, a portion of the velocity that they tended to take from the inclination of the pipe or from the equivalent head pressure of water. Since the co-efficients in the formula for flow presented are variable for different conditions of velocity and diameter and smoothness of pipes, and since they can be determined only by practical experiment, the series given to us by Mr. Darrach will prove exceedingly valuable to those who have to place pipe systems on a large scale.

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CLXII.

(Vol. VII.—June, 1878.)

THE SOUTH PASS JETTIES.

DESCRIPTIVE AND INCIDENTAL NOTES AND MEMORANDA.

By E. L. CORTHELL, C. E., Member of the Society.

Read at the Tenth Annual Convention, June 18th, 1878.

It is nearly three years since the construction of the jetties was commenced.

Two years ago, at the annual convention, we gave you in a very fragmentary manner, an account of the work, and of some of the results obtained at that time.

We propose now to deal somewhat more generally with the subject, and to supplement the descriptive statements with some memoranda incident to the work.

It will be remembered, in the discussion of the subject, that the jetties are still incomplete; that the results aimed at are not yet fully realized, and that many of the phenomena are the results of progressive

works, and are incidents simply of the process of channel making, at which the river has been set at work.

The subject is one which for importance and multiplicity of interesting details is worthy of a volume. In fact, nothing but a full, continuous history of the work, dealing with details as well as with general descriptions and results, can give one a clear idea of the magnitude of the work done, and of the extraordinary results accomplished in so short a time.

Three years ago, a vessel drawing seven feet had great difficulty in passing over this long flat bar of mud and sand. Now, for uniformity, width, depth and navigability, the channel is nearly as good as the Sandy Hook entrance to New York harbor.

Important in every point of view, and, as well known as the subject is, we approach it with no reluctance or hesitation, and boldly give all the actual facts relating to subjects about which there has been such a diversity of opinion among engineers, and in reference to which so many predictions of failure have been made.

We propose for arguments to give facts and results obtained by observations and surveys in which we have perfect confidence, and to take from our map case and note books whatever may relate to the subjects, and to draw from the facts of others when we have not had the opportunity to obtain them by personal observation.

First.—The General Regimen of the River and Passes.

The relation existing between the three passes is so intimate, that it will be necessary to consider them all, and the river itself, in order to understand all the forces at work, and to know how best to meet and to use these forces.

One mile above the head of the passes the Mississippi River is 8 000 feet wide, the approximate depth is 30 feet, the sectional area 240 000 square feet, and the discharge at the flood stage of the river is about 1 000 000 cubic feet per second. The slope of the flood surface of the river between the head of the passes and quarantine station, a distance of 37 miles, is about ¾ of an inch per mile, the slope of Southwest Pass and Pass à l'Outre is about 1 inch per mile, and that of South Pass about 1½ inches per mile.

The banks are low and marshy, and are overflowed by the ordinary flood tide at high river.

The bed of the river, as well as of the passes, is alluvium, easily abraded and carried away by slight increase of current.

The regimen of the passes, as to sectional area and volume of discharge, is variable, and dependent upon several causes, viz.: the different rate of extension of the passes into the Gulf; the state of the tide; the prevalence of winds from certain directions; the growth and subsequent disappearance of mud lumps at the mouths of the passes, and local obstructions in the passes or in the main river immediately above.

On account of the soft nature of the alluvial bed over which the water flows, the equilibrium between sectional area, slope, velocity and volume is very easily disturbed, so that slight and almost inappreciable causes often produce important results. For instance, about four years ago the government dredge was moved from Southwest Pass bar to the bar at Pass à l'Outre. The immediate result was the shoaling up to its normal depth of the Southwest Pass bar, and the deepening on the other through a narrow channel from 12 to 18 feet. The more important result was the deepening and enlargement of the whole section of Pass à l'Outre, from the bar to the head of the passes.

Humphreys and Abbot give the following as the proportional discharge of each pass:

Southwest Pass, 46 per cent.

Pass à l'Outre or Northeast Pass, 46 per cent.

South Pass, 8 per cent.

In 1875 Maj. Howell found the following:

Southwest Pass, 39 per cent.

Pass à l'Outre, 51 per cent.

South Pass, 10 per cent.

Water is not the only element that flows to the sea through the Lower Mississippi and the passes. About one thousandth of the volume is sedimentary matter held in suspension by the current.

The presence of this element, and that, too, such a variable element, is the cause of many phenomena which considerably complicate the problem of the improvement of the pass and bar.

The conditions affecting the ratio and kind of sediment are various.

Each tributary discharges a different kind, and has a different ratio and weight. The ratio of sand to the whole quantity of sediment in suspension is the most important element, for on account of its weight it needs a strong current to carry it out to sea.

Then again, the size of the particles of sand affects the carrying power of the current.

All the facts that it is possible to obtain are being carefully collated from patient and thorough observation, by Capt. M. R. Brown, the U. S. inspecting officer stationed at the Jetties.

The following is the result of one full year's observations to ascertain the amount of sediment carried to sea through South Pass: Total amount, 27,555,900 cubic yards, and as South Pass is about one-tenth of the river, we can assume that the whole amount carried annually to the gulf, after passing Cubits Gap, is 275,559,000 cubic yards.

Second.—The Condition of the South Pass and Bar in 1875.

At the head of the passes a great middle ground shoal, extended from Southwest Pass to Pass à l'Outre, completely across the entrance to South Pass.

Over this shoal not more than 15 feet of water could be carried into the pass.

An island, with a secondary shoal above it, divided the waters flowing into the pass into two channels. Below this island the channel is uniform in depth and width, the latter being about 700 feet, and the former 40 feet, with an approximate sectional area of 23,000 square feet. The pass presents the appearance of a beautiful ship canal, with smooth banks, and deep water quite close to them, with no snags or bars to obstruct navigation.

Five miles below the head of the passes about 27 per cent. of the volume was discharged through Grand Bayou, which had a width of 300 feet, and a maximum depth of 30 feet.

Below Grand Bayou the channel is still uniform and regular, nearly 700 feet wide, but with only 35 feet depth, and an approximate section of 17 000 square feet.

The uniformity is preserved until the land's end is reached, at the mouth of the Pass, when the bank on the east side disappears from sight, and a reef, on which there is but about 3 feet of water, takes its place. A part of the volume of the Pass flows off to the eastward over this submerged bank. The western bank also commences to recede from land's end; the channel begins to shoal up, and more water escapes laterally as we go seaward.

About one mile and three-quarters from land's end, or "East Point," as denoted on the chart, the bar proper is reached, and extends for about 3 000 feet nearly level.

On this plateau there was about 9 feet of water, as a maximum depth, at average flood tide, or about 7½ feet at mean low water. The slope seaward commences at the outer limit of this plateau, and has a descent of about 1 foot in 60 feet.

The question as to what was the rate of bar, advanced before the jetties were commenced, cannot be definitely answered.

The authorities give 100 feet per annum, and it is probably not far from correct.

Third.—THE GENERAL PRINCIPLES ON WHICH THE CONSTRUCTION OF THE JETTIES WAS BASED.

The formation and maintenance, for an indefinite time, of a deep and uniform channel through South Pass, gave a sufficient reason for following the example set by nature, and taught us that the artificial confinement of the river current would, in a short time, produce the same results seaward of "East Point" that had been accomplished at any point between East Point and the head of the Pass, and that the two and a half milles immediately above land's end is no deeper or more regular in section than the two and a half miles from land's end to the outermost limit of the bar would be, if the same plan of bank formation was adopted in artificial construction that the river had used in the past centuries.

Again, as the crest of the bar was 2½ miles from deep water in the Pass, it was reasonable to assume that, if the banks were suddenly extended to the crest of the bar, the new bar, when formed, would be found 2½ miles from the present crest, for the same causes would produce the same effect.

Further, it was believed, that the time required by the Pass to build 2½ miles of banks in its natural condition, would be considerably lengthened under the new circumstances, and that, instead of 125 years, a greater time would elapse, for these reasons: *First*, we believe that the Gulf shore current of salt water, caused mainly by the northeast and east winds, and flowing generally westward along the face of the bar, would be accelerated by the building of the jetties out into it, and at right angles to it, and would carry far to the northward or eastward of the jetties the sedimentary matter thrown out by the fresh water currents. Also, *second*, that a strong and deep volume of fresh water, in place of the sluggish and shallow volume formerly flowing out, would have sufficient carrying and suspending power to throw the sediment

well out into the Gulf before being checked sufficiently to drop its load. Also, *third*, that this strong current, 30 feet deep, would itself perform the work of a dyke and compel the salt water current to go under it, and thus to erode the Gulf bottom over the whole area covered by the discharge from the jetties.

These results were more particularly looked for after the works were completed and the maximum channel fully formed; but during the progress of the work, and while the formative period of the channel continued, and while several million cubic yards of sediment scoured out of Pass and bar would be thrown out of the jetty mouth, in addition to the vast amount of sedimentary matter with which the river is charged we expected alternate scour and deposit both within the jetties and beyond them. We looked for marked and ugly irregularities that might give us trouble to control, guide and shape to uniformity.

The character of the material through which the channel was to be made was very variable; first clay, then sand, then a combination of the two, and through it the struggling current seemed to seek for a subteranean relief from its confinement.

Fourth.—The Detailed Plans of the Work.

In the location of the jetties several objects were aimed at.

First, to give them a direction parallel with the outflowing current, and at right angles to the shore currents along the face of the bar. *Second*, to give as wide an entrance for vessels as it was possible to obtain. *Third*, to remove the jetties themselves far enough from the channel to ensure their safety. The maximum channel to be obtained, according to the Act of Congress, is a depth of 30 feet and a width o 350 feet at that depth. The dimensions are remarkable, considering the section of the Pass itself, which generally has a much smaller section. It is still doubtful whether such a section, when obtained, can be maintained without danger to the jetties.

The location and alignment of the jetties can be seen best by an inspection of Chart No. XIV. The width between the guide piles on the side of the jetties is 1 000 feet. The clear width, between the jetties, is 930 feet. The lines drawn at right angles to the jetty lines are wing-dams, provisional works intended to accomplish three objects: *first*, to compel the current to make the deep channel midway between the jetties; *second*, to induce deposits behind them and against the jetties; *third*, to hasten the erosion of the bar.

In order to hasten the confinement of the current and give an opportunity to work further out to sea with the mattress work, the first mile of the east jetty was built of sheet piling, after a foundation of mattresses had been laid in advance.

Two rows of square piles, 12″ by 12,″ were driven 12 feet apart, the piles in each row being 8 feet apart. The tops of these piles were sawed off to the same height, and two traveling drivers ran on them and drove the sheet piles against a waling timber, 6″ by 12″, which was bolted to the river row of piles. The sheet piles, which were 5″ by 12″ at the large end, and 3″ by 12″ at the small end, were driven about 15 feet into the ground, or until they were flush with the top of the waling timber, which was about level with "average flood tide." The sheet piles were drift-bolted to the waling timber.

Another provisional work was constructed along the first 3 000 feet of the west jetty. This consisted of plank aprons set on a foundation of mattresses, and held to the guide piles of the jetty by sheet piles driven in front of them.

All this provisional work was long ago supplemented by permanent mattress work. As the jetties are built of mattresses, it may be proper to describe them here.

A mattress is built of willows.

The willow found in this section of the country is not easily made into fascines ; it is too stiff and crooked and branchy, and has none of the pliability of the osier willow used on dykes in Europe.

Most of the willows used on this work were obtained from an extensive swamp about 25 miles above Port Eads.

This vast willow swamp, threaded by numerous sloughs and bayous, was formed by deposits of sediment carried through a crevasse by the river.

This crevasse is called the "Jump," and occurred about 40 years ago, and at that time there was a bay with 5 or 6 feet of water where we now procure the willows.

There are probably 100 square miles of ground of a somewhat amphibious charater. We have already harvested from it about 100,000 cords of willows, and so rapid is the growth that we are now using material cut from the stumps of trees cut off in the early part of the work.

The stern wheel steamboat "Grafton" tows the empty barges to the

jump, takes them down into the bayou or "Passes," as they are called, for it is a little delta all by itself, leaves the barges at the camp of the willow contractor, takes away the loaded barges, and tows them to the jetties.

Willows have also been cut in considerable numbers from the river bank, as high up as the mouth of the Red River.

The mattresses are built on inclined timber ways; the inclination being 1 in 10. The timbers are 12″ by 12″, and extend back from the water's edge about 60 feet.

At one end they are a few inches below low tide, and at the other about 5 feet above the ground.

The timbers are parallel with each other, and spaced about 6 feet apart.

To avoid friction, a ribbon of 3″ by 3″ stuff is spiked to the timbers, and the upper side planed off to an edge.

The timbers and ribbons are well greased. The frame work of the mattress is made of yellow pine strips, 2½″ by 6″. They come in various lengths from 20′ to 40′.

The mattresses are usually 100 feet long, and the strips are laid to this length by butting the ends together and fastening them by a lap of the same kind of material, spiked to the strip by 5-inch cut spikes.

These strips are laid at right angles to the timbers, and 5 feet apart from centre to centre; holes are bored with 1½″ auger, 5 feet apart, and hickory pins, turned to fit the holes, are driven into them and secured on the under side of the strip by an oak wedge and 20-penny nails, toe-nailing the end of the pin to the strip.

If the mattress is to be 40 feet wide, there are 9 of these strips, and they are held in place by inch boards, tacked to them temporarily.

A barge of willows is placed alongside the ways, opposite the mattress frame, and workmen standing on the willows pass them out to those that stand on the frame, who place the willows at right angles to the strips between the pins to a depth of 6 inches; another layer of the same depth is placed on the first, and at right angles to it, and in the same way two more courses are laid, all at right angles to each other. Cross-binders are now cut the width of the mattress, and holes having been bored in them, so that they will fit the distance between the pins, they are driven down over them and pressed down by levers.

Wedges and nails are then driven in the top of the pins. The mat-

tress is now ready for launching. The tug comes alongside, moves the barge and pulls off the mattress by means of a strong bridle line, which has been built into the mattress.

The mattress floats about four inches out of water. The tug takes it in tow, and tows it to its place at the guide piling. A stone flat or barge is brought down and placed against the floating mattress. The stone is carried out and spread evenly over the mattress, until it sinks to its place. Another mattress is placed on the first, and another still, until the surface of the water is reached, when the last mattress is pulled on at high tide by a steam pile-driver engine.

The last course of willow work is built in place on the Jetty, by putting pins into the cross-binders of the top mattress, and then filling up with willows to the top of the pins, when cross-binders are put on as in a mattress. The whole work is then heavily loaded with stone. The foundation mattress is generally about 40 feet wide, and the last mattress 20 to 25 feet. It has not been found necessary, generally, to have any slope seaward, as the deposit back of the Jetties is so rapid that the sea side of the work is fully protected.

The last 600 feet or 700 feet of the sea ends of the Jetties needs a wide base and slope seaward, to protect it from the violence of the waves. This work is being done as fast as opportunity offers.

Fifth.—Instrumental and Hydrographic.

This subject, if entered into in detail, would require many pages and be of much interest ; but the space allowed will not permit a lengthy description of the methods employed by which, each month, a complete hydrographic survey, covering an area of nearly 13 000 000 square feet, and a mean depth of 20 feet, is made in four days, and plotted in another day. Necessity has been the mother of invention, and taught us many expedients, to not only insure accuracy, but speed, in surveying and plotting.

It has been the practice for two years, at least, to make a survey on the first of each month, very similar to the one shown on Chart XIV. From these surveys records are kept, which will show eventually the whole history of the work. For a complete account of methods employed to make these extensive surveys in so short a time, I beg leave to refer to an interesting article by Mr. Max. E. Schmidt, Chief-Assistant Engineer, which recently appeared in the "Engineering News." May 30th, 1878.

In this connection, we refer to Chart XIV, which is made from the latest survey, and on which are drawn a few curves from the United States Coast Survey Map of 1875.

The plane of reference is "Average flood tide," as established by the Secretary of War, and all surveys are referred to this plane.

The tides are diurnal, and have an average range of about 14 inches, with an extreme range of 6 feet, which is the range between the highest and lowest waters ever known since the Jetties were commenced, caused by extraordinary local disturbances of winds and storms.

The principal points to call attention to on the chart are, *First:* The changes that have occurred between the Jetties, showing an increase of 15 feet in depth at the present shoalest point, with a much greater increase elsewhere. *Second:* The shoaling that has occurred on the sea side of the Jetties, especially at the West Jetty, where at some points there are but 2 feet of water, where originally, there were 16 feet. Also, laterally seaward of the first mile of the East Jetty, for where formerly there were three feet of water, the land now is a foot above the average tide, and covered with a thick growth of grass and reeds. *Third:* The shoaling against the Jetties on the river side, protecting them from the river currents.

Through the Jetties, however, though they are fast filling up among the willows and rock with sediment, there is still a considerable leakage. It is safe to say that at least 15 per cent. of the volume that passes East Point is lost through the Jetties before reaching the end at Station 118. The Jetties have generally been raised to the level of average flood tide, though from the natural subsidence of the material they are below that level at many points.

The principal work now being done is the loading of the Jetties heavily with rubble stone, especially near the ends of the Jetties, where they are exposed to wave action.

Experience during the provisional stage of the works, when, as yet only the core of the work has been built, proves to us conclusively, that the most exposed portions of the Jetties, when completed according to the plans designed, will be amply strong to resist any wave force that may come against them.

Sixth.—The Wing Dams.

They have been referred to already, but they have played so important a part in creating the channel that they should be described fur-

ther. They are temporary, generally, and can be removed whenever the object for which they are built is attained.

They are constructed by first driving a row of guide piles, 20 feet apart, against which are sunk foundation mattresses about 30 feet wide and 2 feet thick. These foundation mattresses connect at one end with the foundation mattresses of the Jetties, and at the other extend a short distance beyond the outer end of the intended wing dam. Across the river end of this foundation is sunk an apron mattress, about 70 feet long and 30 feet wide. A row of piles, 8 feet apart, are driven through the foundation mattress about 12 feet from the lower edge. A waling streak of 5″ by 9″ timber is bolted to them about 2 feet above average flood tide.

The wing dam mattresses are usually about 75 feet long, two to each wing dam, and are as wide as necessary to extend from about 2 feet above the waling timber to the foundation mattress. They are generally 2 feet thick, and many of them have a tight board bottom. They are raised to a vertical position by a steam pile driver and pinned close against the piles by driving piles about 20 feet apart and tieing them to the main row of piles.

While speaking of the wing dams we will describe and discuss certain phenomena which we believe to have been caused by these wing dams, and in the examination of which we have had the opportunity of investigating some of the geological questions relating to the bar.

Accompanying this paper are several plates, which will serve to illustrate the phenomena alluded to.

On plate XV are drawn portions of the jetty lines, and also certain wing dams or spur-dykes built out from the shore or the jetties at right angles generally to the current. The dotted lines drawn under the wing dams indicate that so much of them are intact, and that the remainder of the wing dam was either never finished or had fallen into decay.

Wing dams I and II, on the west side, are really the effective dykes, for those on the east side are built in shoal water of not over 10 or 12 feet depth, often much less, while Nos. I and II are, at their river ends, in 25 feet to 28 feet of water, and well out into the strong current.

Wing dams I and II were built in October, 1876, and the others shown on the sketch were built previously. As soon as the river rose in the spring of 1877 the effect of wing dams I and II was very marked. A

very rapid current was found to flow past them, and strong eddies under them. The whole channel, from Station 40 up to wing dam No. I, and even above it, commenced to improve at once.

The river commenced its annual rise about the last of March, and had nearly attained the flood stage of the year on the last of April. The readings on the Carrollton gauge, at dates affecting this subject, were as follows: April 30th, 10.60; May 25th, 11.00; June 6th, 11.00; July 5th, 10.60; August 1st, 7.10.

Opposite Station 50, the greatest depth, in April, was 33 feet. On the 25th of May it had increased to 75 feet, and an enlargement laterally had taken place. On the 5th of July, the basin had reached its maximum depth of that year of 95 feet, and had assumed the extraordinary proportions shown on Plate XV. Between July 5th and August 1st a slight deposit had taken place in the deepest portions, the river having declined considerably between these dates. Special attention is called to Plate XVI, on which are drawn surface float lines, and the slope of that portion of the water surface affecting the basin. The unusual velocity between Stations 30 and 36 is fully accounted for by an examination of the slope.

These slope observations were made on gauges set carefully by instrumental leveling and fastened to the piling of the East Jetty. They do not necessarily show the exact slope that existed midway in the channel between the wing dams.

If the slope of the central thread of the current below the head of the West Jetty could have been ascertained it would no doubt have shown that there was quite a fall from the middle of the pass towards the jetties; and if gauges set along the West Jetty could have been observed they would have shown a reversed slope, and would have given a reason for the strong current moving along the West Jetty flowing *up stream*. It will be noticed that there are no wing dams on the West Jetty from Station 38 to Station 71+30, a distance of more than 3 000 feet. The wing dams on the East Jetty, opposite this space, are in shoal water, and in a dilapidated condition, and none of them could have had any great effect upon the current.

The width of channel-way from Station 26 to 30 is not over 600 feet.

The width at Station 50 is about 900 feet.

With the data in our possession we may be able to find out some of the reasons that induced the river to excavate so great a basin in so short a time.

The float-lines on Plate XVI show that the outward moving current became narrower and narrower, like water forced through an orifice under pressure.

The least width of the current is found some distance *beyond* the greatest contraction. In some respects this action illustrates the principle of the "*Vena Contracta*" of Newton.

The particles of water in the centre of the stream flow straight out and at right angles to the edges of the orifice. The particles passing out at the sides of the vein converge, and the angle of convergence corresponds to the head of water against the edges of the orifice; or, in our case, against the protruding wing dams.

The wing dams are not water-tight by any means, and the loss through and over the first, at Station 26, is arrested by those at Station 30, and the second cause is given for still greater convergence of the particles; and so with the third set of wing dams at Station 35.

Thus the reasons for the convergence and for crowding the main volume into still narrower limits is easily seen.

This convergence continues until the wide open space at Station 45 is reached.

The contraction is, however, preserved to near Station 55, where it widens out rapidly to either side, flowing off on the side slopes previously mentioned; thus extraordinary eddies are induced, and they, in turn, pushed forward by the forces behind them, seek to enter or crowd against the main current, and thus from either side force the latter into still narrower limits.

The width of straight current at Station 48 may be assumed as 130 feet—sometimes greater, sometimes less. The line of demarcation between straight and eddy currents was usually very readily discerned by the eye. It often happened that in towing mattresses the eddy current would catch one end of the mattress and whirl it about tug and all.

We have the data for calculating approximately what the depth *should* be at Station 48.

Observations for the discharge of South Pass a short distance above the jetties, at the flood stage of the river for that year, gave 56 000 cubic feet per second, The volume passing at Station 48 was about 55 000 cubic feet per second, some loss having taken place through the jetties above this locality. The mean velocity of the straight current obtained from the surface velocity and using the co-efficient 0.89 is 4.45 feet per

second. The width being assumed as 130 feet, we have the elements of an equation for depth.

$$\text{Thus } (4.45 \times 130)\, x = 55\,000.$$

$$x = 95 \text{ feet.}$$

which was the maximum depth observed.

The reason for the deep excavations at the sides of the basin may be found in the existing eddy currents.

We are all aware, from our general experience, of the power of an eddy.

During the low river season the channel was somewhat rectified by wing dams built out from either jetty at Stations 45, 52 and 65.

During the time of this extraordinary scouring action the eddies induced an unusual and, as it were, a counter-balancing depositing action, and they threw off the material on the exterior of this almost circular basin much as a wheel throws off the mud by centrifugal force. The effect of all this irregular action on the channel below was injurious, and also exhibited a dangerous tendency towards undermining the West Jetty.

At the lower extremity of the very flat slope shown on Plate XVI. there was no tendency towards channel deepening, and the 750 000 cubic yards scoured from this great basin over-loaded the current in the lower reaches of the jetties, and produced a temporary tendency to shoaling the channel.

The effect of the flood river this spring showed the futility of attempting to rectify such extraordinary currents by wing dams built out from the jetties.

The deepest water is now at Station 45, where it is 108 feet.

Of late the ends of all wing dams above the West Jetty have been torn down back to the line of the jetty produced.

Now, that the cause of the formation of the basin is partly removed, we may look for a rectification of the channel,

With all the trouble that has been caused by this phenomenon it has yet produced a broad channel above and below the basin, and the tendency is now towards an elongation of the excavation.

This great basin afforded an opportunity of making examinations of the character of the material composing the bar in this locality.

An instrument weighing about 85 pounds was made, which had a sharp steel point for penetrating the material at the bottom, by allowing

it to drop from the launch. This steel point was fitted into a 2½ inch gas pipe about 8 inches long.

In the side of this point was an opening about 2 inches square with a projecting lip on the lower edge to catch the material when the sounder was drawn up. This short piece of gas pipe was screwed into another piece about 2 feet long. So that when the cavity was filled the point could be unscrewed from the longer piece and the material removed by a spoon. A mass of lead was run about the gas pipe to give it weight sufficient to strike the bottom with great force. To keep the point downward, while falling, a white pine post about 2½ feet long was fitted into the gas pipe and secured to it firmly by side straps of iron. A ring with a half inch rope attached was fastened in the end of the post, and the machine was dropped from the side of the steam launch, the rope running through a sheave set in a post about 5 feet above the rail of the launch.

The material brought from the different localities and depths was dried, then pounded up, if clay, and sprinkled on gummed paper. Several specimens are sent with this paper, the object of this examination being to ascertain the original character of the bar. A survey was made at the time of making those observations. The chart of this survey when compared with previous charts gave the data for making a sketch showing the line of demarcation between original material and any areas over which shoaling may have taken place since the jetties were commenced, and on which new deposits must have been made.

On this sketch, No. XVII, the points from which the specimens were taken are located and noted according to whether the material was clay, sand, mud or half clay and half sand by different kind of circles. A characteristic curve is also drawn at 26 feet depth, as the line between clay and sand seemed to be approximately near this depth. A record which was kept of the depth at which each kind of material was met by a dipper dredge working at Station 22, shows that the line of demarcation between sand and clay is at about 28 feet depth. Except on the crest of the bar there is no doubt that the limit of clay is about 26 to 28 feet, and that below that depth sand is generally found to an indefinite depth with occasional pockets of clay or of sand and clay mixed.

Seventh.—Interesting Phenomena.

For the purpose of offering facts for the study by those interested in the phenomena of the river and jetties, a chart No. XVIII. is given, which shows some of the active elements and their results. The in-

timate relation between velocity, discharge, kind and ratio of sediment, scour and deposit are more clearly shown by this little sketch of curves than by any lengthy description or by voluminous tables. The figures from which some of those curves are made, are the result of many days and weeks of tedious work.

On this sketch is drawn the average position of each characteristic curve, whose history has been followed as closely as circumstances would permit.

They are the 20, 24, 30 and 40 feet curves seaward of the end of the jetties, and exhibit approximately the position of the outer face of the bar at each one of the dates recorded. The points for the curves are ascertained by means of ordinates spaced 50 feet apart. There are 24 of those ordinates, commencing on the line of the East Jetty produced and extending about 200 feet west of the West Jetty produced. They have a common initial line, from which the distances are measured on the ordinates to the point where they intersect the curve. The average distance on all the ordinates gives the point.

The curve of the river surface at Carrollton is also drawn. It may be noted here that extreme low water reads minus 1.62 on the gauge, and extreme high water reads plus 15.74 on the gauge. Ordinary low water reads about plus 2.0, and ordinary high water about plus 13.5.

The tides at low river cause a fluctuation of 8 inches on the gauge, but at high river or when the gauge reads 13.0 they become *nil*. This gauge has been read constantly for many years—and to its readings are referred many important river observations from Carrollton to the Gulf.

It was set in 1848 by Prof. C. G. Forshey, member of the Society, so that its zero should be at the level of mean tide of low river.

The sediment and sand curves are also drawn. They show the ratio of sediment to water by weight. This curve is taken from the records of observations made by Capt. Brown, whose careful and patient work is solving many of the important phenomena connected with the jetties. The specimens from which the record is made were taken from the South Pass at Port Eads.

There is also drawn a curve showing the total amount of excess of scour over deposit from East Point to 1 000 feet beyond the ends of the jetties—expressed in cubic yards.

A comparison of these curves shows some interesting results, the most important of which is, that considering the curve of the Carrollton

gauge the cause, all the other curves are results, and follow it very closely in point of height and time.

Thus the curves of the face of the bar are changed by the rise and decline in the river, by the scour between the jetties and by action of storm waves and sea currents; but the sand curve exerts an important influence also. Thus we notice, that on the first of August, 1877, the sand curve rises suddenly and to an unusual height. Immediately after this curve reached its highest point the 20, 24 and 30 feet curves extended out suddenly and to their greatest limit.

The curve of excess of scour does not represent all the material that has been removed, for there has been an extensive deposit along the river side of the jetties, extending out some distance from them. The whole amount of material moved, irrespective of deposit, is 5 252 566 cubic yards. The total of excess of scour over deposit to date of April 5, 1878, is 2 853 987 cubic yards, as shown on the curve.

The points on this curve are obtained by comparing surveys made at the beginning and end of each characteristic stage of the river at Carrollton, as nearly as those periods can be fixed to conform to the times of the regular monthly surveys, which are made on the first of each month, or as near that date as circumstances will permit. These characteristic stages of the river are: rising river, flood river, falling river and low river.

A skeleton chart is made on tracing paper from the two charts which show the condition of the channel at the beginning and end of the period —generally about three months in duration. This skeleton shows the areas of scour, deposit and no change, and is divided into three characteristic sections: the first from "East Point" to "Kipp Dam;" the second from "Kipp Dam" to the end of the jetties; the third from the end of the jetties to 1 000 feet outside. The width of the sections is the width between the jetties, except above Kipp Dam, where it extends from the East Jetty to the west shore. The difference in depths over these areas multiplied by the area gives prism of scour or deposit.

The result just worked out by comparing the survey of January 1, 1878, with that of April 5, 1878, is one of the most satisfactory ever found, and shows that the power for channel making by the jetties is by no means exhausted.

The river has been at two-thirds flood stage—the sediment curve is seen to be very prominent, and yet the skeleton shows an uninterrupted

scour from East Point to 1 000 feet outside the jetties. The only area on which deposit has occurred is near the jetties and away from the channel.

The prism removed from the channel during this period is 928 825 cubic yards, divided as follows on the sections numbered according to the above description.

Commencing above Kipp Dam.

Number I, 69 463 cubic yards.

Number II, 778 133 cubic yards.

Number III, 81 229 cubic yards.

The average deepening over the area scoured in section Number II is $8\frac{23}{100}$ feet. The scour in excess of shoaling over the whole area considered from East Point to 1 000 feet outside is 619 267 cubic yards. The excess of scour over deposit in the "1 000 feet outside" is 39 309 cubic yards, and as the area outside is 1 000 000 square feet, the average deepening is $1.\frac{06}{100}$ feet.

Eighth.—Changes in the Gulf bottom beyond the end of the Jetties.

The most important question, next to that of channel formation, is the condition existing seaward of the jetties. This question has become much more important than it would otherwise be, by the published statements and predictions, that have been made prior to and since the commencement of the work.

Preliminary to the discussion of this question, it will be conceded by all, that the greatest shoaling in front of the jetties would occur while they were being constructed and the channel was forming, for two reasons.

1st. During this time, now, of nearly three years' duration, there has been thrown out into the gulf nearly 3 000 000 cubic yards of heavy sedimentary matter in excess of all deposits.

2nd. The current force has been much weaker during the formative condition of the channel than it will be when the maximum depth is secured; for it is fair to presume that a current 30 feet deep will have much more carrying power than one 12 feet deep.

Now, what are the facts derived from two and one-half years' work? What is the condition of the Gulf bottom in front of the jetties, with a depth over the bar of about 23 feet? During the latter part of October of last year, a careful and minute survey was made to ascertain these

facts. The result is given on Chart XIX. and in the following tables, on which a comparison is made with the United States Coast Survey of 1875 previous to the commencement of the jetties.

Table of Comparison

Of the Quantities of Water in 37 Subdivisions of an area containing about 0.278 square miles, or 178.37 acres, immediately seaward of the end of

South Pass Jetties,

Between the dates of May, 1875, and October 1877, to accompany Comparative Chart—Plate XIX.

Number of Subdivision.	Area of Subdvision in sq. ft.	Mean loss in depth over Subdivision since May, 1875, in feet.	Mean gain in depth over Subdivision since May, 1875, in feet.	Quantity of Water lost in Subdivision since May, 1875, in cubic yds.	Quantity of Water gained in Subdivision since May, 1875, in cubic yds.	Number of Soundings in Subdivision.	
						May, 1875.	Oct. 1877.
1	500,000	....	4.1227	....	76347.	35.	223.
2	500,000	0.6909	....	12795.	....	26.	149.
3	500,000	....	1.4288	....	26459.	24.	85.
4	500,000	...	0.3682	....	6818.	19.	49.
5	500,000	0.8363	....	15488.	....	10.	35.
6	50,000	....	4.7833	....	8858.	5.	17.
7	100,000	0.3333	....	1234.	....	4.	19.
8	150,000	....	6.3208	....	35116.	7.	20.
9	200,000	2.8667	....	21234.	....	6.	21.
10	250,000	....	1.5750	....	14583.	8.	13.
11	50,000	0.0583	....	108.	....	7.	13.
12	100,000	....	1.3222	....	4897.	4.	14.
13	150,000	....	5.9833	....	33241.	5.	14.
14	200,000	1.8133	....	13432.	....	8.	13.
15	250,000	3.7083	....	34336.	....	3.	15.
16	100,000	....	0.3444	....	1276.	10.	23.
17	100,000	....	1.4944	....	5535.	5.	13.
18	200,000	....	4.1733	....	30913.	6.	18.
19	250,000	....	1.6972	....	15715.	10.	20.
20	100,000	....	3.8167	....	14136.	7.	13.
21	100,000	....	3.1222	....	11564.	6.	10.
22	200,000	....	3.0533	....	22617.	14.	10.
23	250,000	1.4944	....	13837.	....	8.	13.
24	100,000	....	0.0611	....	226.	4.	14.
25	200,000	....	0.2767	....	2049.	10.	20.
26	250,000	....	2.8055	....	25977.	10.	16.
27	60,000	....	2.2667	....	5037.	2.	15.
28	100,000	....	2,7722	....	10267.	4.	12.
29	200,000	....	2.3966	....	17753.	7.	15.
30	250,000	....	2.0861	....	19316.	11.	19.
31	60,000	....	0.0417	....	92.	2.	7.
32	125,000	2.9095	....	13470.	....	7.	19.
33	250,000	....	1.3028	....	12063.	7.	15.
34	250,000	....	5.9055	....	54681.	14.	22.
35	125,000	....	2.0286	....	9392.	10.	11.
36	250,000	....	2.4194	....	22402.	8.	17.
37	250,000	2.7889	....	25,823.	....	4.	19.

Key to Combinations.

Combination "A" contains subdivisions 1–5 inclusive.
" "B" " " 1–15 "
" "C" " " 1–23 "
" "D" " " 1–31 "
" "E" " " 1–37 "

Letter of Combination.	Area of Combination in sq. ft.	Mean *loss* in Depth on Combination since May '75, in ft.	Mean *gain* in Depth on Combination since May '75, in ft.	Quantity of Water *lost* in Combination since May, 1875, in cub. yds.	Quantity of Water *gained* in Combination since May, 1875, in cub. yds.	Number of Soundings in Combination.	
						May, 1875.	Oct. 1877.
A	2,500,000	.....	0.8785	.....	81,341	114	541
B	4,000,000	.....	0.7269	.....	107,690	171	700
C	5,300,000	.....	0.9965	.....	195,609	237	820
D	6,520,000	.....	1.1443	.....	276,328	287	928
E	7,770,000	.....	1.1661	.....	335,572	337	1,031

Area of scour.....4.311.000 square feet.
" shoaling.....3.459.000 "

Total area.....7.770.000 "

Average increase in depth over area scoured,

$$\frac{335.572 \text{ cub. yds.}}{4.311.000 \text{ sq. ft.}} = 2.102 \text{ feet.}$$

The accompanying map and the foregoing tables explain themselves.

The method employed in the calculations may be open to the charge of interpolation of soundings; but any other method was impossible, owing to the paucity of the Coast Survey Soundings in many of the subdivisions.

The interpolation is made with all possible accuracy, and the number of soundings in each division is given in the tables, that anyone may judge of the possibility of error.

The *fact* of the deepening seaward of the jetties is established by this survey, and it is fully coroborated by a survey of May, 1876, which was compared with the same Coast Survey chart used in the above calculations.

The surveys of Captain Brown, which are far more extensive, attest the accuracy of the result given in the tables. In a comparison of two of his own surveys, one of June, 1876, and the other of June, 1877, he shows that there has been an average deepening of 1 foot and $3\frac{7}{10}$ inches over an area of 542 acres in front of the jetties, the boundary lines of the area on each side radiating from the ends of the jetties, and extending seaward of them one mile, with a width at the outer limit of one mile and a half.

We offer the following reasons for this deepening :

1st. The jetties are built out into and at right angles to a salt water current, which at certain seasons of the year and under certain conditions of the winds, flows along the face of the bar.

This current may be due entirely to the winds, or to other causes in part. It is not always in the same direction ; generally it flows to the westward, but often to the eastward, and sometimes there is no perceptible current either way. During the fall and winter and early spring months the winds prevail from the northeast and east, and the current to the westward is often well marked and strong.

Thus the jetties are dykes built into a river of salt water and at right angles to its currents. This causes a "race" in front of the jetties, extending its influence some distance beyond them.

2d. Over the old bar there was a sluggish outward river current about eight feet deep ; over the new bar there has been a current with an average depth of twenty feet for the last two years. The velocity and power of this current is much greater than that formerly existing.

This strong volume of fresh water cannot be thrust aside at once, nor, on the other hand, can the volume of salt water be dammed up by it. The result therefore of a meeting at right angles of these two forces, is a depression of the salt water current into the very soft gulf bottom, and a consequent scour and removal of the material to restore the sectional area encroached upon by the new and deeper fresh water current. As a corroboration of these views, attention is called to the areas of scour and deposit on the chart, the former being shown by the unshaded portions and the latter by the shaded portions. Well defined channels of scour can be traced across the whole area and at right angles to the discharge of fresh water from the jetties.

These facts, so fully corroborated by independent surveys, made at different times by different parties, with the additional fact taken from

them, viz.: that nearly all the contours in front of the jetties from twenty feet to eighty feet, or as far as any examinations have been carried with sufficient detail for comparison have receded, show conclusively that the whole outer slope of the South Pass bar has advanced *landward* instead of *seaward.*

How much the jetties will need to be extended annually, or even when an extension will be necessary, no one can predict in the face of these indisputable facts.

This we do know, and we emphasize and restate and insist upon it, that under more unfavorable circumstances than can ever recur again, the jetties have caused a scour, instead of a deposit, in front of them.

In a late official report of Maj. C. W. Howell, U. S. A., he offers the opinion that this deepening is due to influences similar to those operating in crevasses of the river bank.

Let us for a moment compare the conditions existing at the end of the jetties and those at Cubit's crevasse.

This crevasse occurred about fifteen years ago. It is three miles above the head of the passes, on the east bank of the river.

The fall between the surface of the water in the river at flood stage and the adjoining bay is from three to four feet.

The almost immediate result of the crevasse was the formation of an extraordinary crater about 180 feet deep, or about 130 feet deeper than the river near by.

A very short distance from this great depth there was not more than six feet of water. This condition has existed to this date. I am credibly informed that the launch of an engineering party, drawing three-and-a-half feet, was hard aground at the bow, while over the stern the lead went down a perpendicular precipice over 100 feet deep. Here we have a great volume of water forced under the pressure of four feet head against the bank of the river; the result is a tremendous vertical eddy that makes and maintains an extraordinary excavation. The fresh water volume pushes to one side the salt water and sweeps over the shoal ground. Where this flow, some distance from the river, is checked, the bay is filled up by a deposition of the sediment, and grasses and willows are already growing in abundance.

At the end of the jetties, the head of water is not more than three inches at the maximum. Instead of a river bank and shoals to strike against, the fresh water current flowing out of the jetties moves out

gently over a stratum of salt water. The stratum of fresh water becomes thinner and the salt water deeper as we go from the end of the jetties seaward.

Now, much of the deepening, shown on the chart, has taken place where we know by observation that there is a depth of fresh water at flood stage of the river of say twelve feet, moving gently and smoothly seaward, without boils and eddies, on a stratum of salt water forty feet thick.

Can it be imagined even that this thin layer of fresh water is disturbing and throwing into commotion in its gentle flow a layer of denser and heavier salt water under it?

Again, how account for the deepening that occurs during low river when there is *no* head of water and the salt water fills the jetty channel and the Pass and the tides flow in and out almost without obstruction?

We know that most of the deepening, or a large part of it, occurred during low river, and, without any doubt, from the effect of the littoral current; for the current itself can be plainly distinguished, and the deepening occurs at the same time.*

Ninth,—The Head of the Passes.

With all the peculiar and interesting phenomena connected with the jetties, and the engineering difficulties connected with them, there was nothing at the mouth of the Pass that presented the difficulties that have been met at the head of the Passes.

In order that a full knowledge may be had of the conditions existing there, a map of the Mississippi River and Passes at the point under consideration is given, Plate XX.

The U. S. Coast Survey Map of May, 1875, has been used for comparison, and the fifteen feet, twenty feet, twenty-six feet and thirty feet curves are drawn on the accompanying map which was made from a survey of March, 1878.

The South Pass is a bayou compared with the two large Passes.

The depth into it was only about fifteen feet, while nearly thirty feet could be carried into the other two Passes.

In order to deepen the bar, partially blocking the channel into South Pass, it was necessary to obtain erosive power in some way. This could only be done by an increase of velocity, which could be obtained only by giving the current flowing into South Pass a greater slope, and this

* See page 158.

could only be the result of a greater head of water above the Pass in the river.

This head of water was obtained by the works constructed and shown on the map; but a head of water could not be raised above the head of South Pass without also raising it above the other passes, and thus making side slopes into them, down which, for the time being, some of the volume rightfully belonging to South Pass flowed into Southwest Pass and Pass à l'Outre.

However the works were designed, as shown on the map on the supposition that the South Pass would not allow itself to be largely robbed of its volume, and that while a portion of it might, for a while seek the other passes it would return whenever there was an unobstructed entrance into South Pass.

There is no doubt that the process of channel making at the jetties was delayed many months by the partial loss of the volume belonging to South Pass.

The volume that flowed into South Pass formerly spread over a wide expanse and the lines of the neutral axes were as follows: that between South Pass and Pass à l'Outre intercepted East Dyke about 600 feet below "Cluster;" that between South Pass and Southwest Pass intercepted "T-head Dam 2" about 300 feet below its upper terminus.

The work first constructed was "East Dyke." This was built in the winter of 1875 and the spring of 1876.

It was intended to intercept a portion of the volume flowing into Pass à l'Outre and deflect it into South Pass.

The order of the construction of this dyke, which was built solid of mattresses laid horizontal, was as follows:

Work was commenced at the upper end in December, 1875, at low river, and the foundation course was laid down stream; then the second couse was laid in the same way. At about the time of the completion of this course, the spring rise of the river came and almost immediately shoaled the channel near the dyke, so that the depth was about the same as that on the mattresses. A new plan was then adopted by constructing the dyke to the surface of the water from the lower end, working up stream, and completing it as we went.

It was thought that as the dyke, as previously constructed, had acted like a submerged dam, inducing deposit above it, it would become a real deflecting dyke, if built to the surface, working up stream. The current

did seem to make desperate efforts to break through the deposit made in front of that portion earlier constructed, but it was unable to do so, for the depositing tendency overbalanced the scouring power. The eastern channel shoaled up to eight or ten feet.

The plan of the works, as shown on the map, was then designed and carried into execution, and a change of base was made from Pass à l'Outre to South West Pass.

"East Dyke" was used as a base to work from, and the confinement of the volume in the lower line of the western channel was the ultimate object.

"Dam No. I," built in a similar manner to the wing dams described previously, was first constructed in the fall of 1876; then a T head across the west end of it extending up to "New Cluster." A dam was thrown across the eastern channel between the head of the island and "East Dyke."

This latter work was of too temporary a nature, and was undermined and much of it washed out.

A more substantial and permanent structure was afterwards built to replace it, and known as "Island Dam."

The "Dam II." was also built in the fall and winter of 1876, and a "T head" was built parallel to the opposite "T head Dam I." The opening between these two T heads was 800 feet. During the winter of that year and the early spring of 1877 a channel, about 20 feet deep and 50 feet wide, was dredged through the shoal lying between the T heads.

As soon as the river rose in the spring, this channel quickly widened and deepened, and has continued to improve ever since.

After the channel had been formed, it was found that the current impinged too severely upon "T head Dam 2," and that the shoal lying under "T head Dam 1" was too extensive. In order to remedy those evils, the "T dam I" was torn down between "New Cluster" and "Dam I." Below "Dam I," nothing but a foundation course of mattresses was built.

The "T head Dam 2" was built in a permanent and substantial manner. An extension was added to it in the spring of 1877, and constitutes that portion that curves to the eastward.

Ganging simultaneously the three Passes, it was ascertained that there had been loss of volume by South Pass. This was in the summer of 1876.

In the fall of that year a sill of mattresses was laid across the South-west Pass, connecting "T Dam 2" with the west shore of that pass.

In the spring of 1877 a similar sill was laid across Pass à l'Outre, connecting the upper end of "East Dyke" with the east bank of that pass.

The object of these sills was to prevent any further loss of volume, and to induce more water to flow into South Pass.

As these sills were important and somewhat peculiar in construction, and as the difficulties were considerable in laying them, we will describe them briefly.

The mattresses were constructed at the Jump, about 12 miles above the works; they were towed down the river by a stern-wheel steamboat, and tied up to anchorages built some distance above the works.

The tug took them from this position and towed them astern to the sill.

About 175 feet above the lower line of the sill, which was made of mattresses, 70 feet long, 25 to 40 feet wide, and 2 feet thick, anchorages were built about 150 feet apart. They were constructed of three piles, driven in the form of a triangle, about 8 feet apart. These piles supported a plank platform, and were held securely together by 5″ by 9″ timbers bolted to them, and on which the planks were spiked. In order to make an angle of about 45 degrees between the level of the platform, which was about 2 feet above the water, and the bed of the river above the platform, two piles were driven about 30 feet above the platform, and bolted together, after which a ¾″ chain was slipped over them and let fall to the base of the piles; the running end was made fast to one of the platform piles and drawn taut with the engine of the steam pile-driver.

Ranges were put up to show the lower line of the sill, which was 70 feet wide, the length of the mattresses, and they were then—two or three, and sometimes four at a time—placed in position; each one as it was dropped down by the tug and made fast by long head lines to the platforms, was hauled to its place beside the others or against side guide piles by the driver. When all that were to be sunk at one time had been placed in position, side by side, and pulled close together, so that the brush was jammed, the pile-driver swung around to the opposite side of the mattresses and drove two, sometimes three, guide piles close into the bushy edge of the outer mattress. The mattresses were all lashed securely together and to the piles, so that in sinking they would not break apart. One, and sometimes two, stone flats, carrying about 50 cubic yards of stone, were placed above and against the upper edge of the mattresses.

The stone was carried off the flats first to the lower edge of the mattresses and evenly distributed over it, sinking it from the lower end to just the surface of the water. When the whole fleet of mattresses, sometimes 160 feet in width, or 4 mattresses, 40 feet wide and 70 feet long, was covered with water, the men commenced rolling the stone off of the flats on to the upper edge of the mattresses. By this means, by slacking gradually the lines holding the flats to the anchorages, they dropped down over the sinking mattresses, the men meanwhile throwing off the stone as rapidly as possible. Soundings were taken on the mattresses as they sank, so that they could be put down level on the bottom.

When they were found to lie smooth on the bed of the river, they were well loaded, and the lines, all except the lashings, were taken off. As many of these mattresses were sunken in 30 feet of water, with a current sometimes from 3 to 4 miles per hour, with the piles and anchorages swaying back and forth, with mattress lines so taut that it seemed as though they would snap asunder, the difficulty of the work can be imagined.

Neither of these sills has ever been disturbed by the currents. Their continuance was necessary to success, and all possible pains were taken to secure it.

The effects of all these dykes, dams and sills is already very marked.

1st. A deep scour through the entrance channel, extending to the narrow channel between the island and the west shore.

2d. Over the whole area included between "East Dyke" and "T head Dam 1," where formerly there were 15 feet of water, there has been a general shoaling, so that now there are only about 2 feet of water. This shoaling has extended below "Island Dam" and above "Dam I," far up into the river.

On the west side, there has been considerable shoaling above "Dam II."

3d. Changes have occurred, and are occurring, which are very favorable for the channel.

Above the Southwest Pass sills, extending to the upper limits of the survey shown on the map, and from the west shore half way out across the Pass, there has been an average shoaling of about 1½ feet during the last 12 months. The 30 and 26 feet curves have advanced down stream about 700 feet during the last year, immediately above the South Pass channel, and in the line of current flowing into it.

We may reasonably conclude, that the mattress sills are having some effect upon the regimen at the head of the Passes.

Although the obstruction is slight, it must yet exert an influence.

During certain conditions of the wind, the "ripple" or "break" of these sills can be seen entirely across the Passes.

With a bed so easily moved, the volume of water now exerting itself to "jump" these sills will slowly but surely seek the less obstructed entrance of South Pass, so that we may look for a still deeper channel into South Pass as a result of these sills; at any rate, we will recover the volume which may have been lost.

If these sills should be raised, especially the one across Southwest Pass, the head of water above them would be increased, and a side slope would be found to exist towards South Pass channel, on which the water would flow into the latter.

Whether the problem is fully solved or not, the indications for complete success at the head of the Passes are very favorable.

There are many items and even subjects of interest that have been omitted necessarily from a paper of this kind and extent.

The details of the construction of the work closing Grand Bayou; the method by which the slopes of the Pass and river have been ascertained; a description of the powerful hydraulic dredge boat *G. W. R. Bayley;* the history of the construction of the jetties, with the quantities of materials used; and the commercial advantages that have already resulted from opening the river's mouth to deep draught vessels.

When the whole work is finished, and final success attained, there might be written a personal history of the enterprise, of the most thrilling interest, in which might be related the discouragements, temporary failures, and obstacles of all kinds, which have required and found a heroism, and a patience, and a persistence, and a sublime faith on the the part of two men (one an honored member of our Society), who, as engineer and contractor, have carried the work through to success against obstacles and through darkness and trouble, that long ago would have appalled or utterly discouraged any but the bravest spirits.

FOOT NOTE.—The report of Captain M. R. Brown, U. S. Inspecting Officer for the year ending June 30th, 1878, now being published, shows an average increase of depth of 1 8-10 feet during the last twelve months over the area of 1¼ square miles beyond the jetties' ends.

CHART

OF THE

SOUTH PASS JETTIES

OF THE

MISSISSIPPI RIVER

SHOWING THE

SITUATION OF THE WORKS AND THE

CHANGES MAY 1875 TO

Note: Soundings are expressed on feet and tenths, and refer to the grade of the navigable channel. The Jetties are shown as they were. The survey of 1870 was made by the U.S. Coast Survey, under the direction of A.D. Manceau, Assistant. The survey of 1874 was made by the Engineer of the Engineers under the direction of B.S. Cunningham, Assistant Engineer.

SOUNDINGS

May 1875 April 1876

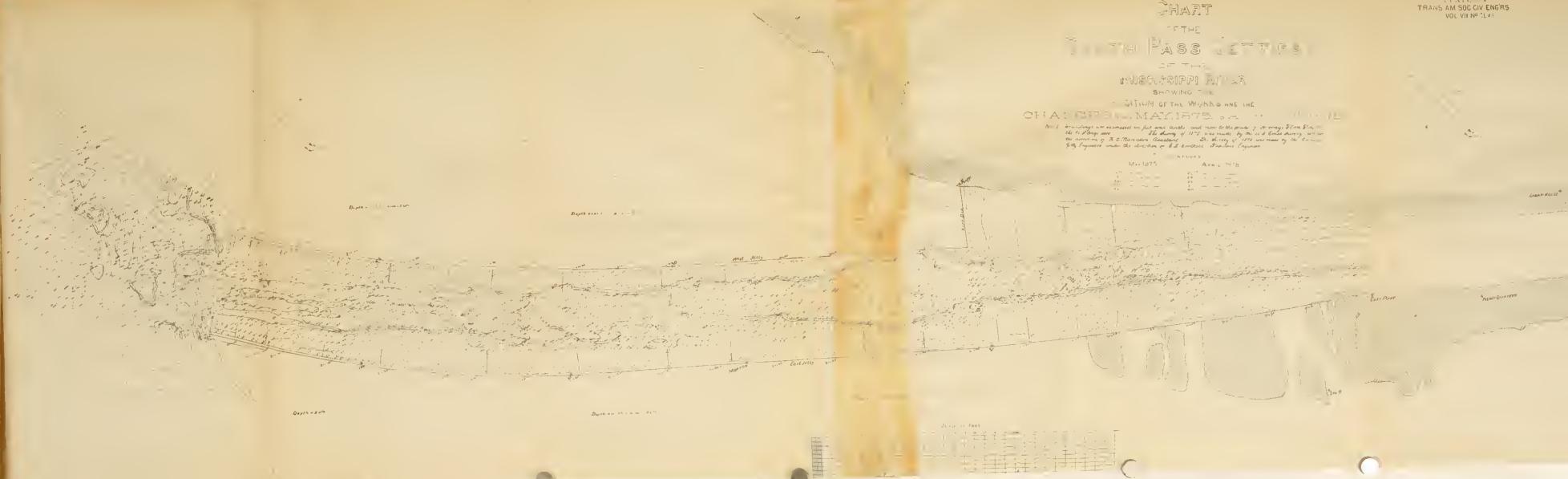

PLATE XV
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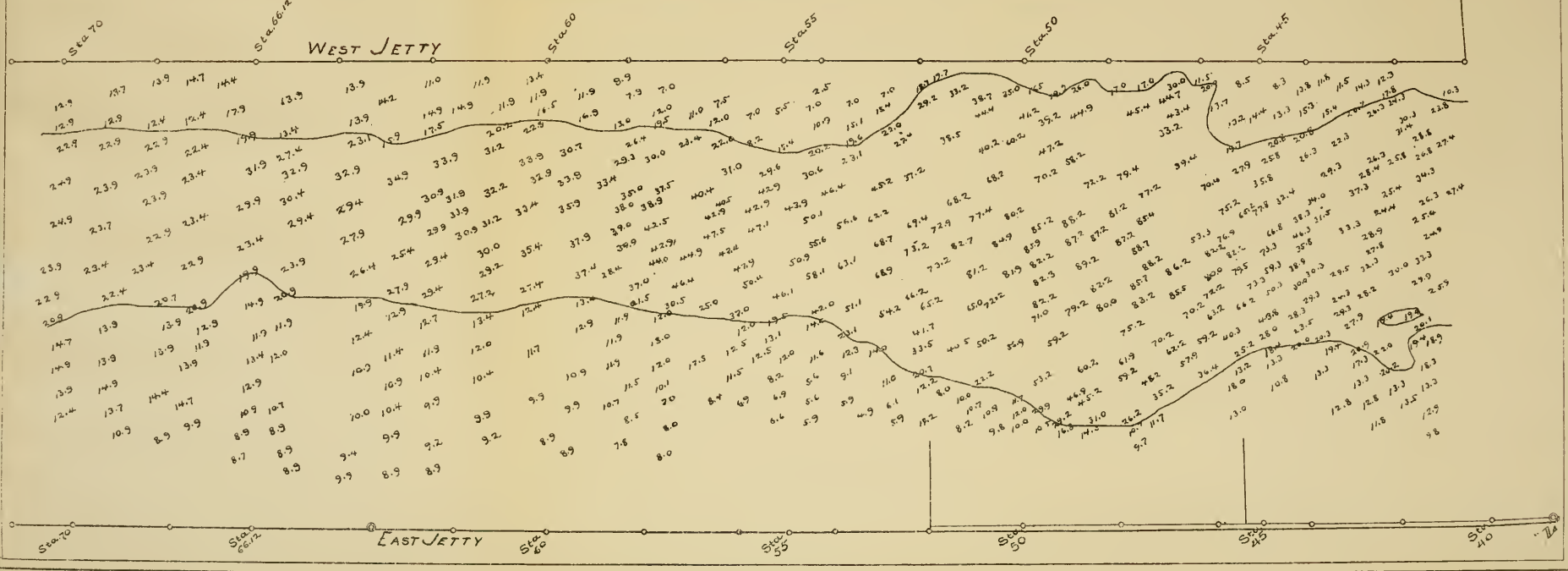
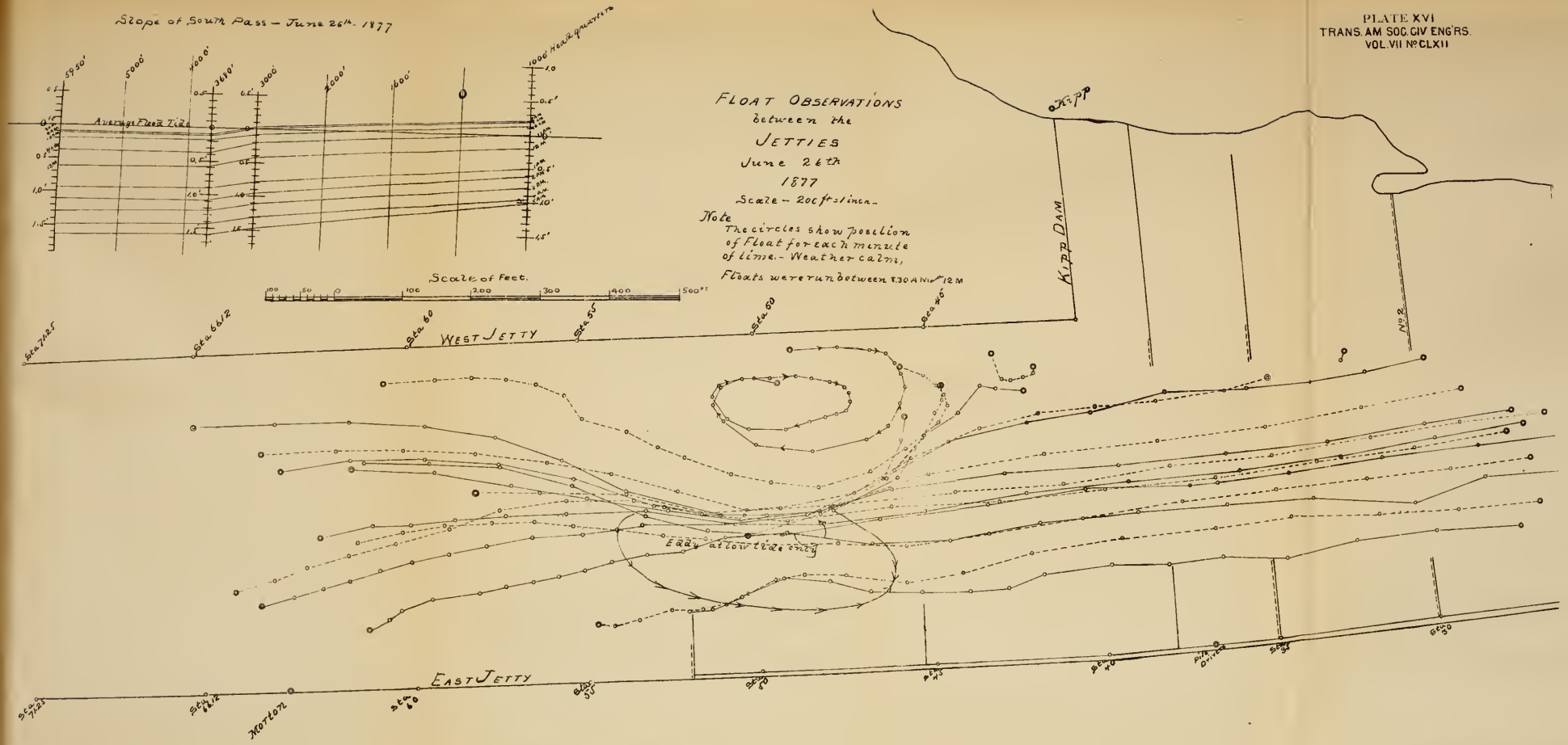
Survey of a Part of the JETTY CHANNEL.

August 1st–2nd 1877.

Scale.




Slope of South Pass – June 26th. 1877
Average Free Tide
FLOAT OBSERVATIONS
between the
JETTIES
June 26th
1877
Scale – 200 ft = 1 inch –
Note
The circles show position of Float for each minute of time. – Weather calm,
Floats were run between 8.30 AM & 12 M
Scale of Feet.
KIPP DAM
WEST JETTY
EAST JETTY
Eddy at low tide only
Motor

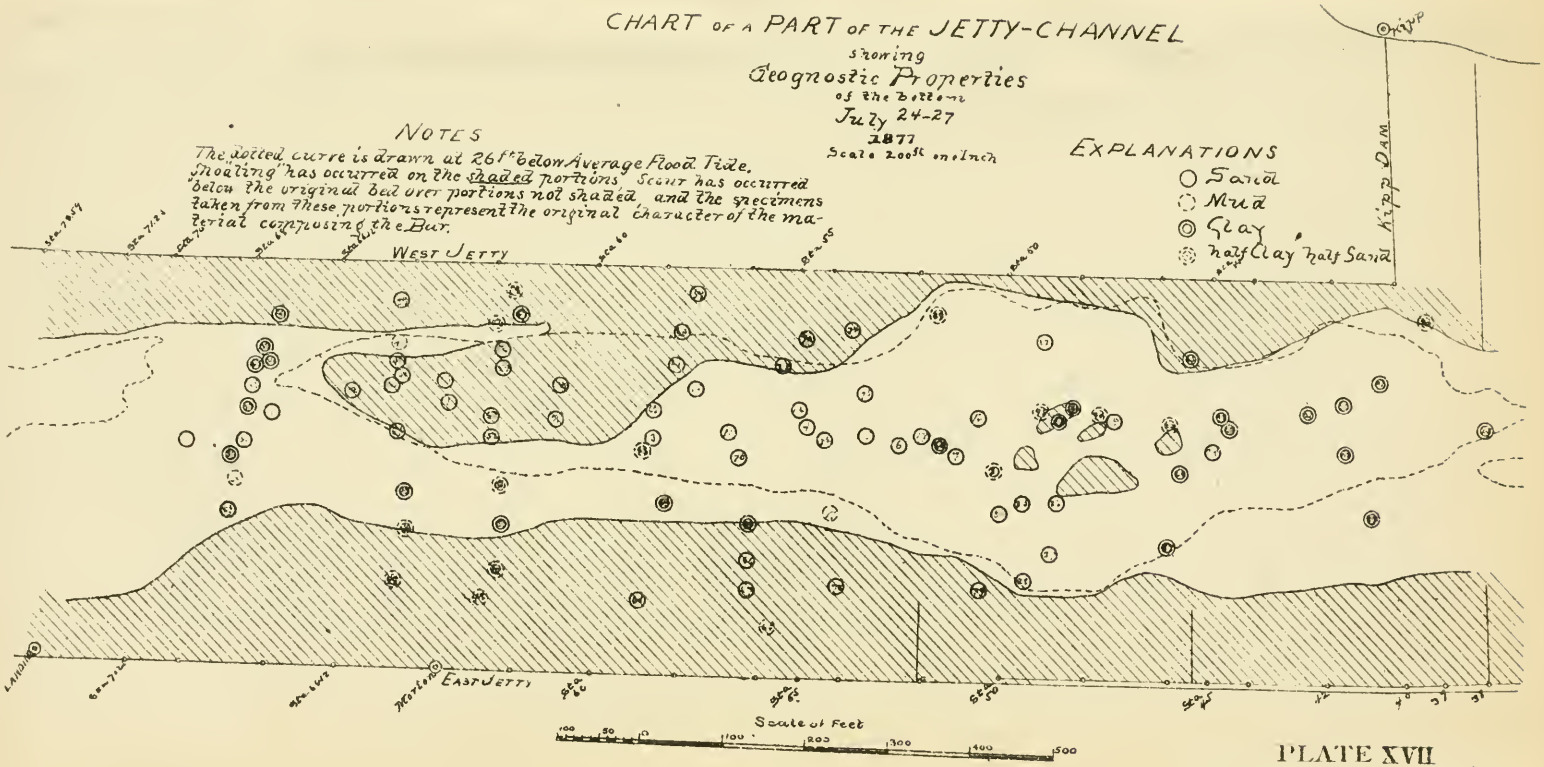


PLATE XVII
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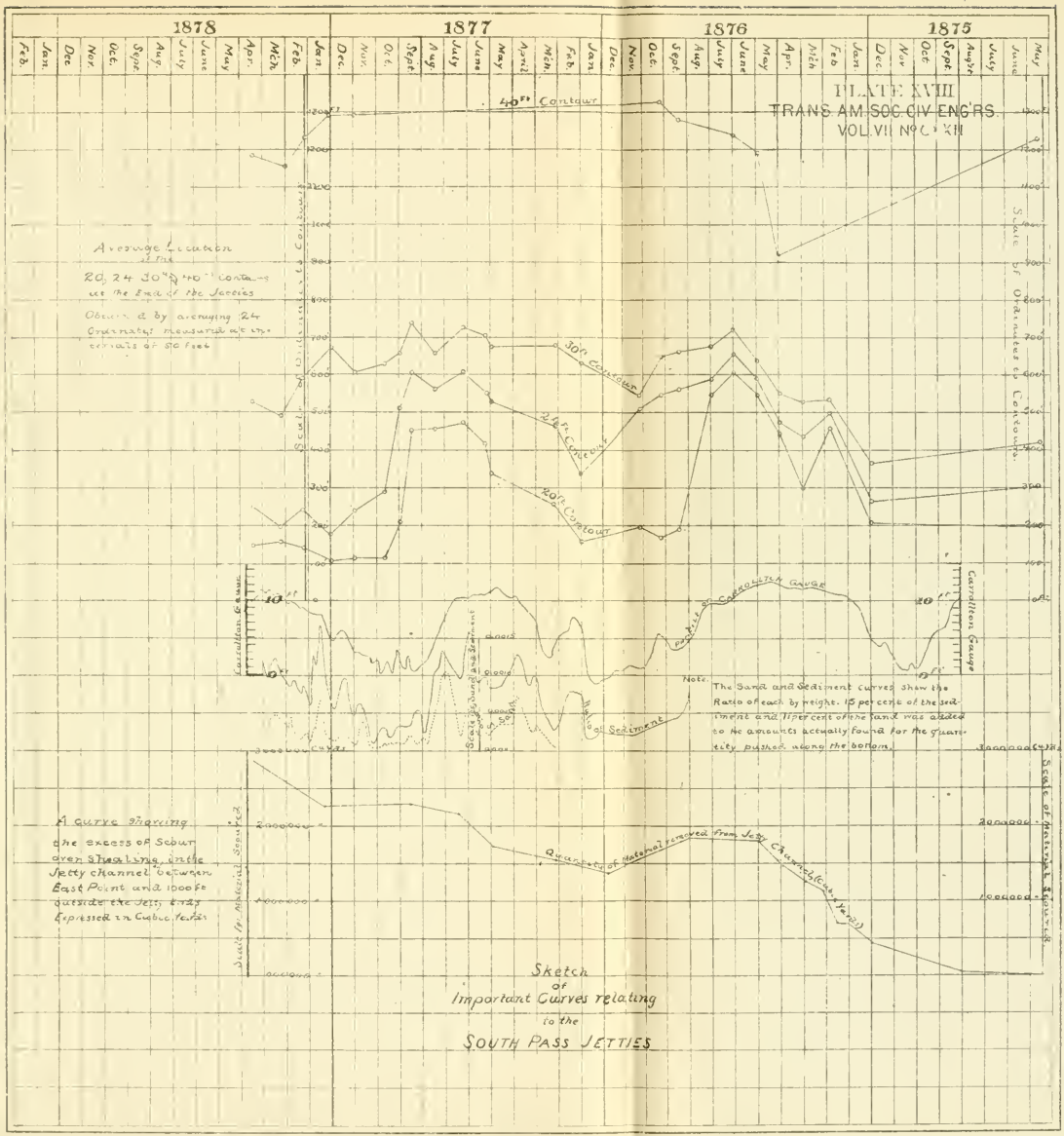
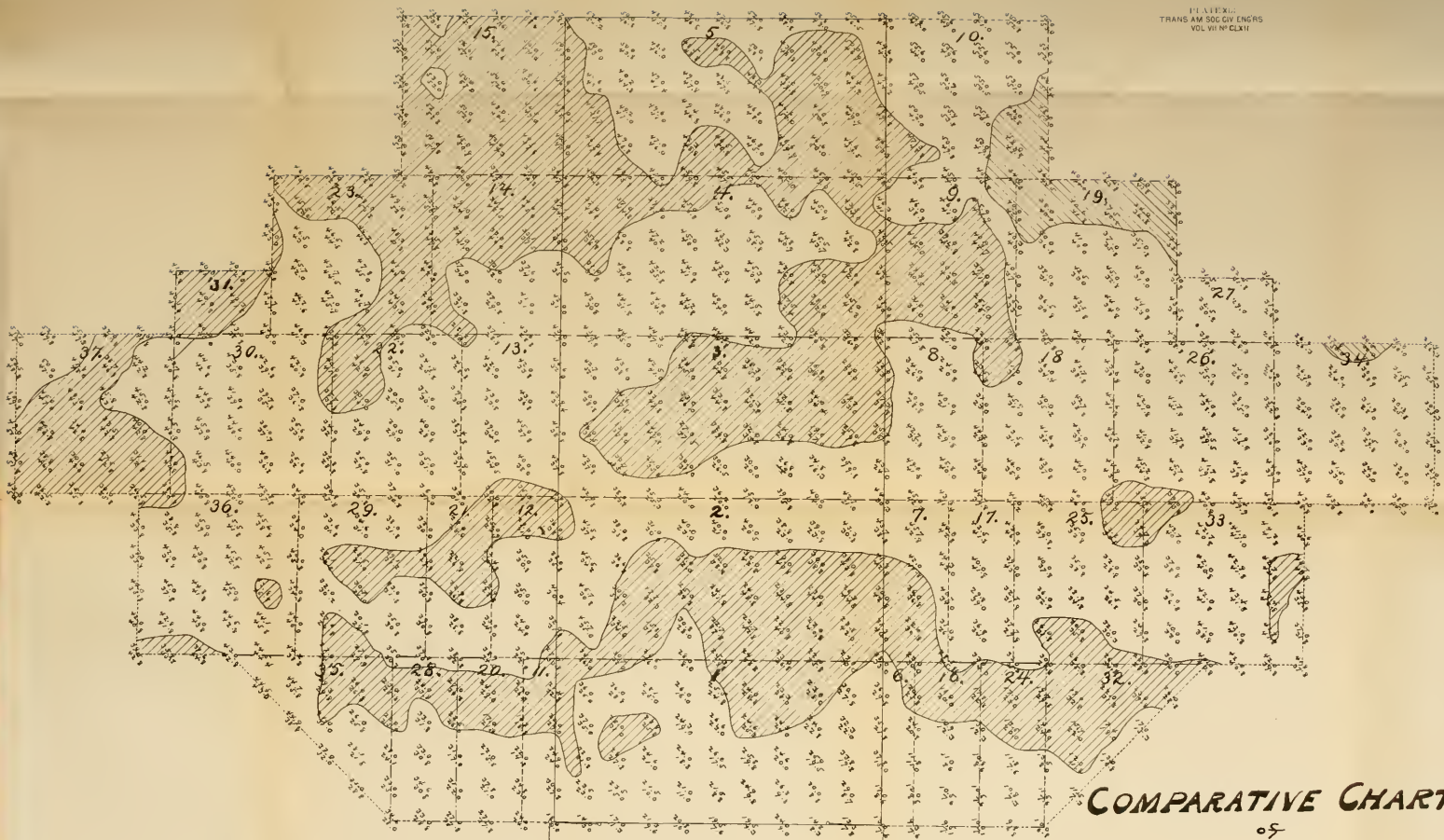
PLATE XVIII
TRANS. AM. SOC. CIV. ENG'RS.
VOL. VII No. CXII





COMPARATIVE CHART

of

an Area of about 0.278 Sq. miles or 178.37 Acres

immediately Seaward of the end

of the

SOUTH PASS JETTIES

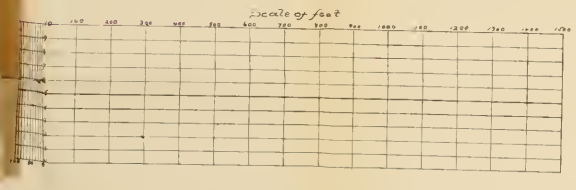
between the dates

of

May - 1875

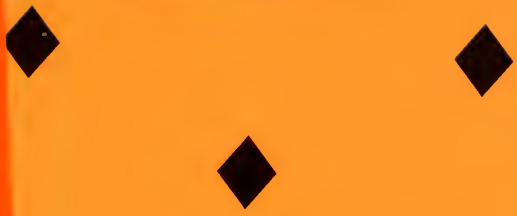
and

Oct. 20th 23rd, 1877.



Note. Soundings are expressed in feet and tenths of a ft.
Upper figures denote depth in Oct. 1877.
Lower " " " " May 1875.
" " should occupy the same place
as " " figures — they are displaced for convenience of writing. Areas shaded denote Shoaling —
Blank Areas " " Scour —

Here



AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

(Vol. VII.—June, 1878.)

DISCUSSIONS ON

THE SOUTH PASS JETTIES.

By CHARLES W. HOWELL, E. L. CORTHELL, C. SHALER SMITH, and J. FOSTER FLAGG.

CHARLES W. HOWELL.—Through the courtesy of Mr. E. L. Corthell, member of the Society, I have been favored with a manuscript copy of that part of his paper on "The South Pass Jetties" which treats of the deepening in the Gulf, immediately in front of the jetties.

I am thus enabled to offer, at the present time, a discussion of that portion of his paper.

About one year ago, if I am not mistaken, it was announced that, over a selected area, immediately in front of the South Pass Jetties, there had been discovered a deepening in the Gulf averaging 4½ feet.

Shortly after this announcement, Capt. M. R. Brown, inspector of the work, officially reported an average deepening of one foot three and seven-tenths inches, but in making his calculation covered a greater area than that before covered. Objection was made to his introduction into his calculation of certain sub-areas (called side areas), over which there

had evidently been great shoaling, but which were, it was contended, not sufficiently well covered by soundings given on the coast survey chart used as the basis of comparison.

At the time it appeared very strange to me that the deepening reported should have occurred, and judging from the several years of experience in sounding off the bars of the several Passes of the Mississippi, as reported to me by my assistants employed upon the work, I was disposed to think that the several results were more due to inaccurate soundings than to actual scour.

Afterward I suggested (see my last annual report) that scour *might* have been caused, over a *limited* area, by eddies, similar to those observed in crevasses, and no doubt to be found in all cases where water, under head, is suddenly released from confinement and projected against a denser body, either stationary or in adverse motion.

In view of the discovery announced in the paper before us, that, over the area of which the paper treats, there is nearly always a strong current flowing out of the South Pass, and frequently a very considerable current flowing at right angles to it, I am not disposed to press my suggestion nor abandon it, but find some reason for return to my original opinion.

Under the conditions stated it would, no doubt, be a very difficult matter, if not a hopeless undertaking, to obtain accurate soundings immediately in front of the jetties.

Giving due weight to selection of areas, the variety of results so far presented may suggest correctness of this opinion.

The author of the paper under discussion frankly admits interpolation of soundings to supply deficiency, no doubt, in the coast survey chart on which he bases his comparison.

While fully assured that this interpolation has been as fairly made as any one could make it, it is yet desirable that we should be informed as to the method employed, and also that the interpolated soundings should be so designated upon the chart (No. XIX.) accompanying the paper. The importance of this may appear from the great regularity with which the soundings have been plotted, and from a knowledge of the very considerable and sudden irregularities found in the outer slopes of the bars of other passes, where a few feet difference horizontally has frequently shown several feet difference in depth.

I have looked upon interpolation in such cases (as a method of com-

parison) as one to be avoided if possible, and have considered the selection of limited areas as apt to lead to erroneous conclusions. I will, however, offer a calculation based on the figures given in the large central rectangle (chart XIX) enclosed at the sides by the lines running outward from the jetty ends and covering the axis of discharge along which it would be reasonable to expect the greatest deepening.

My calculation results as follows :

Average deepening $\frac{57}{1000}$ ft.

It is this portion that is best covered by the coast survey soundings, (if I remember rightly), and these soundings were made before the construction of the jetties had increased the difficulty of obtaining accurate soundings over this area. It was to be expected that with currents of considerable velocity passing over this area at right angles to each other, soundings made with the greatest care would indicate an average deepening, inasmuch as the Gulf current, in passing under the axis of the river current, should apparently be given its greatest scouring effect, and also aid in deflecting the sounding line from a perpendicular.

On examining Chart XIX. one is first struck with, what may not be inaptly called, the topographical features of the gulf bottom over this area.

There will be noted three valleys, with suspicion of a fourth, and three well defined mountain (?) ranges (pardon the hyperbole), with reasonable expectation of a fourth, if the chart had been carried a little further out.

The axis of each valley and range is approximately at right angles to the axis of the jetty channel.

The valleys are undoubtedly valleys of erosion and the ranges due to deposit or upheaval, as will appear from the chart, and from the following table compiled from it :

FROM END OF JETTIES OUT.

VALLEYS.		RIDGES	
Mean Average Increase of Depth.	Maximum Increase.	Mean Upheaval.	Maximum Upheaval.
No. 1.			
7.498 feet.	21.2 feet,	9.782 feet.	24.8 feet,
No. 2.			
11.187 feet.	24.1 feet.	6.520 feet.	22. feet.
No. 3.			
5.341 feet.	13.6 feet.	4.935 feet.	9.5 feet.
Part of No. 4.			
2.666 feet.	6.2 feet.		

I assume the ridges to be due to upheaval for two reasons :

1st. Because it does not appear reasonable to expect deposit in such position and arranged in such order.

2d. Because at other passes I find, from years of survey and observation that the same phenomena are presented, and that the ridges are due to upheaval of the mud-lump stratum, and form what I have called the nucleus of bar formation.

One notable fact developed by this apparently reasonable selection of area is this, viz., that in order to obtain the average stated in the paper it was found necessary to include certain side areas, affected no doubt by the horizontal eddies, and to exclude nearly all beyond.

Taking the central area alone, and then comparing it with the total, leads to the conclusion that the axis of discharge of the pass is represented on the gulf bottom by a ridge, and that ranges 1, 2, 3, &c., are but spurs of this ridge.

This would appear very singular if we did not know the tendency toward bifurcation, which all the passes of the Mississippi, except the South Pass, heretofore have shown within the time covered by authentic record.

It is also noticeable that the maximum of deepening and of upheaval decrease as we proceed from the jetty ends gulfward.

This is precisely what has been noted in crevasses during their early stages, and what has, in their case, been ascribed to vertical eddies caused by water, under head, tumbling over one obstruction to butt against another, and over that to meet a third, and so on.

The heads of Cubitt's crevasse and of the Bonnét Carré crevasse are now about equi-distant from the level of the Gulf. During high water in the river their fall is about as follows, in the order named: 3 to 4 feet and 20 feet, yet the depths of first crevasse hole are about as follows: 123 feet and 53 feet, which would indicate that depth of erosion is more dependent on date of delta formation than on head of water. Hence we are led to believe that a head of only 3 or 4 inches in the jetties may create quite deep holes, or valleys, in the bar formation in their front, which is of the newest formation. However, whether the average deepening (?) immediately in front of the South Pass jetties be wholly or partly due to crevasse effect, or whether it be wholly or partly due to gulf currents, is a matter of secondary importance.

Mr. Corthell emphasizes the statement: "That under more unfavorable circumstances than can ever occur again, the jetties have caused a scour instead of a deposit in front of them."

The opinion as to more unfavorable circumstances not being likely to present themselves, does not appear to me as well founded, yet if it should prove not to be, jetty application at the mouth of the Mississippi will probably be abandoned in the course of a few years.

So important a matter is well worth consideration.

In the first place, we learn from the several published reports of the inspecting officer, that for several hundred feet from the projected outer ends of the jetties it was found such a difficult matter to secure foundation on the newly made portion of the bar (where even the guide piles driven gradually went down under their own weight and action of the waves), the maintenance of these portions, at full height, was not persisted in. It was, apparently, discovered that such maintenance would be a very expensive task.

Now let us assume that ridges No. 1 and No. 2 continue to rise at the rate shown in our table, we must believe extension of the jetties will be called for at an early date. Not only completion of the troublesome few hundred feet cited, but extensions over valleys No. 1 and No. 2.

Of course such extension would not be impossible, but it would evidently be very costly, and similar extensions might not afterward be undertaken.

I cannot believe, as Mr. Corthell does, that the greatest difficulties have been overcome. I look for these in the near future.

The difficulty does not alone lie in this very important one of frequent extension into the Gulf over a newly made sedimentary deposit of great thickness and little sustaining power as a foundation, but it also lies in the predicted and observed shoaling of the whole body of the Pass; in the great uncertainties which must attend any attempt to force an increased volume of water through the Pass, and in the upstream growth of the bar at the head of the Passes.

E. L. Corthell.—Major Howell has reciprocated the courtesy which he alludes to, and has kindly furnished me a copy of his remarks to be read in the discussion of my paper on the "South Pass Jetties."

As a considerable portion of his remarks and much of his argument is consumed in attempting to show, that the results which I speak of, as facts, are illusions brought about by inaccurate soundings, I will say:

1st. It is reasonable to suppose that the soundings taken by one corps of professionals is as reliable as those of another, but when one is engaged in a special investigation, and the other in general surveys, the former is generally supposed to work to a nicer degree of accuracy. So in the surveys under discussion, I give the preference to Capt. Brown's party rather than to Major Howell's.

2d. It is an error to compare the difficulties under which Capt. Brown labored with those that the Coast Survey party met, for the simple reason that Capt. Brown compared two of *his own* surveys, and made no comparison with the Coast Survey.

3d. The survey of Capt. Brown cannot be compared with the one that is alluded to, as disclosing a deepening of 4½ feet—since the former covers in its comparison only one year, while the latter covers two years.

4th. The survey made in October, 1877, which forms the basis of comparison with the results of the Coast Survey of 1875, a chart of which is given, was made under the most favorable circumstances that could possibly exist.

The difficulty (?) which Major Howell speaks of, resulting from cross currents, did not exist, for it was made at the low water season, and there was no river discharge to interfere with accuracy. There was a straight current across the mouth of the jetties, and at right angles to them, with a velocity of about 1½ miles per hour. The soundings made on lines run *against* the current, *with* the current, and *across* the current, checked closely with each other.

5th. Capt. Brown states that accurate soundings can be made to a depth of 100 feet. The deepest sounding on the chart in question is not much over 50 feet.

The difficulties which Major Howell's party has met with, exist in deep soundings, from 100 feet to 300 feet or deeper. This is the first intimation we have ever had that our work made immediately in front of the jetties is necessarily inaccurate on account of cross currents.

Granting for a moment, that the difficulties do exist, on account of new and strong under currents flowing across the mouth of the jetties, may we not reason, that a current, that would have such a marked effect on a lead line, would move the soft material of which the outer slope of the bar is formed.

Major Howell regrets that we have not given more fully the details of the interpolation used on the chart XIX, and also given the original soundings themselves.

It may be stated, that *all* the soundings are interpolated, the object being to obtain comparative depths at each corner of each square of 100 feet to make the calculation for the prism more accurate.

The original soundings were not put down, as it would cause great confusion on the chart, but the number of soundings on each subdivision is given in the table accompanying.

An attempt was made to obtain the mean depth by averaging the original soundings, but it was found to be a "mean depth" only in name, especially on subdivision No. I, one of the most important, for the Coast Survey soundings of small depths, over this area, were far the most numerous, and consequently a calculation obtained by averaging the depths would have given a mean depth much too small, and an increase of water prism much too great.

From the careful study of the subject, and of the most accurate methods, I am certain that the results are obtained in the most accurate manner possible under the circumstances.

The selection of the areas for the calculation was made entirely with a view of covering, as nearly as possible, the discharge of the river volume, and *not* in any case with a view, as Major Howell intimates, of including areas over which there had been a deepening.

The interesting description and analysis of Major Howell, illustrating his theory of mud lump formation, is instructive on that point, but we fail to see how it bears on the subject under discussion, for the chart, and

especially the two models, which so well illustrate this subject, show very plainly that the "mountains" have been brought low, and the valleys made deeper by the erosive action of both salt and fresh water currents. The statement made in my paper, that all this has been done under more unfavorable circumstances, than can ever occur again, is not disproved, and the acknowledgment by Major Howell, that the strong fresh water volume thrown out by the jetties has caused a deepening by crevasse (?) action, gives us reason to expect that the same causes operating in the future, with greater force and under more favorable circumstances will produce still greater deepening, and that the reason which existed for withdrawing landward the ends of the jetties, will continue to exist to an indefinite time. That reason was not the subsidence of the ends of the jetties, but because it was entirely unnecessary to build the jetties as far seaward as was contemplated originally.

C. Shaler Smith.—The gist of Major Howell's remarks appears to be contained in the three difficulties which he points out, to wit, insecure foundations for future extension of the jetties, shoaling of the body of the pass, and the upstream growth of the bar at the head of passes.

Concerning these I would suggest that an embankment can be supported on any deposit of the Mississippi river, provided it is given a mattress base of sufficient width; next, that by a proper contraction of the other two passes by means of mattress sills, the water in the South Pass can be made to move at a speed sufficient to prevent shoaling, and lastly, that a modification of the same system of operation may be used so as to effectually control the direction and shape of the upstream growth of the "Head of Passes" bar.

J. Foster Flagg.—The river Magdalena, in South America, has some interest in this connection, as having recently engineered for itself a channel through the bar at its mouth, after having had its navigation obstructed thereby for centuries.

This river flows due north into the Carribbean Sea, and, although draining a much smaller area, it resembles the Mississippi very much in its general characteristics, especially for the last five or six hundred miles of its course, which is in a very flat, alluvial region, covered with dense tropical forests; its water is heavily charged with sediment, and it presents the same features of caving banks, rapidly changing channels, formation of cut-offs, new islands magically springing up in its midst, and large districts inundated in time of high water.

The town of Barranquilla, the principal port of the country, is located on the left bank of the river, about eight miles above its mouth. According to old Spanish charts, and even according to quite recent ones, the island of Gomez, which forms the right bank of the mouth (Boca de Ceniza) had a tongue of land (shown in accompanying sketch) three miles in length, running in a westerly direction across the mouth, and covered with high sand hills and woods, so that the Carribbean Sea was entirely shut out from view to one on the river until fairly passing out at its mouth. The water was very shallow over the bar, and no sea-going vessel thought of attempting an entrance.

As Carthagena lost its commercial importance after the Spanish yoke was thrown off, Barranquilla, from being a mere fishing village gradually became the principal port of export and import of the commerce of the country, the great internal highway for which is the Magdalena. As ships were unable to enter the river, they anchored in the bay of Savanilla, which then had from five to seven fathoms of water, discharging at the village of the same name into lighters, which transferred the cargo by the way of the small channel (Cano), on the south side of the Isla Verde, to Barranquilla.

Gradually this harbor silted up—it now having not over ten feet of water—the Cano also became unnavigable, and vessels were compelled to lie some distance off from Selgar, to and from which all merchandise was lightered, and conveyed over a railroad built from thence to Barranquilla by a German company. At the same time the channel on the easterly side of the island of Gomez, through which communication is had with the port of Santa Marta on the Caribbean Sea to the eastward, was becoming shallower, and the tongue of land was, unnoticed, melting away.

Now, this tongue has entirely disappeared (see dotted line on map), the river is straight, and a clear view of the sea can be had from the river for several miles above its mouth. This tongue, reinforced, doubtless, by the sediment of the river, has apparently been carried by prevailing currents around the Isle Verde, filling up the bay of Savanilla, and the increased force of the river current has cut for itself a good navigable channel through the bar to the deep water outside.

Some eight or ten years ago a sailing vessel of small tonnage was driven into the mouth by stress of weather and anchored off Barranquilla, much to the astonishment of the inhabitants. In March, 1873,

the notorious steamer Virginius (shortly after captured, under United States colors, by the Spaniards, and taken into Cuba) was lying at Gelgar; it suffering from oxidation of the hull, Captain Williams obtained permission of the Colombian Government to take her through the mouth of the Magdalena into fresh water. He was accompanied by Capt. Jaime de Pocaterra, both in entering and in returning some two months later. The Virginius only drew about eight feet of water, but according to Pocaterra, they found, by sounding, a minimum depth of four fathoms, and a width of channel through the bar of some 350 feet. Above the bar the river has a depth of nine or ten fathoms.

Recently, I see by the daily papers, the steamers of the Atlas line, drawing about 18 feet, have entered the river and discharged their freight close to Barranquilla, thus proving, practically, the practicability of the channel for vessels of large draft.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

TRANSACTIONS.

(Vol. VII.—June, 1878.)

Addition to Paper No. CLX.

The author desires to add to Paper No. CLX: "On the Cause of the Maximum Velocity of Water flowing in open channels being below the surface," by James B. Francis, published in Transactions, Vol. VII., May, 1878, the following sentence:

Currents of water have the power of carrying in suspension earthy matters, which, if the water was at rest, would sink to the bottom; the amount which can thus be carried bearing some relation to the velocity. From the observations and experiments in this paper, it would appear that this power is due to the constant movement of water from the bottom towards the surface.

PLATE XXI
TRANS. AM. SOC. CIV. ENG'RS.
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CLXIII.

(Vol. VII.—July, 1878.)

ON A NEWLY DISCOVERED RELATION BETWEEN THE TENACITY OF METALS AND THEIR RESISTANCE TO TORSION.

By ROBERT H. THURSTON, Member of the Society.

READ AT THE TENTH ANNUAL CONVENTION, JUNE, 18TH, 1878.

The determination of the nature of the relation which exists between the resistances of the metals to torsion and to tension, is a matter of both interest and importance to the engineer, and has also great importance as bearing upon the theory of the resistance of materials. It has always been assumed by the engineer and the physicist that there exists a constant relation between these two forms of molecular resistance, and that the resistance of a homogeneous material to rupture or to distortion by tension could be predicated upon the results of experiments determining its resistance to torsion, and that the modulus, or measure, of the latter could be derived from that obtained for the former by multiplying by a constant co-efficient, which has a certain value ascertainable by experiment for every case,

Were the generally accepted theory of torsion correct, which assumes that form of resistance to distortion to be a case of shearing, the above assumption would hold, and the use of a constant factor would be permissible, and would afford perfectly accurate results. This theory makes the resistance to torsion to vary directly as the distance of any given line of particles from the axis, and as the angle of torsion, and makes the molecular resistance to disturbance to be equal to that due to molecular change produced by tension. A study of the strain-diagrams obtained by torsional tests shows that the assumption of resistance varying directly as the angle is correct up to the limit of elasticity. Were the theory correct throughout the whole progress of the distortion, the equation given by the text-book would be the equation of the curve of the autographic strain-diagram.* This is not the case, however, as can as can readily be shown by plotting the equation and comparing with the strain-diagram of any given material.† The equation represents the strain-diagram of no material known in the arts where the curre passes the limit of elasticity.

The discussion of the real form of the true equation of resistance by torsion must be reserved for another paper.

The writer has found, however, that the relation here referred to is a very simple, as well as a constant one, and has empirically determined its character.

It has been customary to determine from autographic strain-diagrams of the metals produced by the torsion machine approximate values for tension by simply assuming the vertical scale of the diagram produced by test-pieces of standard form and size to have a value of 25 000 pounds per square inch for each vertical inch, representing, as is usual, 100 foot-pounds of resistance to torsion. The ratio of 250 to one was originally determined empirically by experiments upon wrought-iron, and was found, as usually applied, to be quite correct. More recent comparisons with cast-iron proved the ratio for that metal to be less; but this was at first attributed to the almost absolute impossibility of securing a perfectly fair pull in testing in the common testing-machine, as well as to the theoretical difference between the brittle and the ductile material. It was not then suspected that the universally accepted relation of the two forms of resistance was incorrect.

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* See "Resistance of Materials." By De Volson Wood, N. Y. 1875. P. 208.

† See Wood's Resistance of Materials, p. 263, and Frontispiece.

Still later experiments, made by Dr. Dudley, with the autographic machine of the Pennsylvania Railroad Company, at Altoona, and comparisons with direct experiments in tension, indicated a scale differing about five per cent. from that which the writer had been accustomed to use. The metals experimented with were all "mild" steels, such as are used in the manufacture of rails. The writer had still further observed that the metals which were marked by an extraordinary ductility exhibited an apparent excess of strength when tested by torsion. These differences, except in the case of non-ductile materials, as cast-iron, were not sufficiently marked, so far as the comparisons thus made went, to seriously affect the value of determinations which were obtained on the assumption first made. They finally became sufficiently obvious, however, to lead the writer to make the attempt to determine by direct comparison the true relation existing between the two kinds of resistance to distortion.

In order to secure the widest possible range of comparison, it was concluded to examine this relation, and to determine the value of the ratio of the scales for tension and for torsion for the widest range of grade of steel that could be found upon the records of the Mechanical Laboratory of the Stevens Institute of Technology. The records of test in both tension and torsion were obtained for a very large number of steels of all grades, from high tool steels containing one per cent. of carbon and upwards, to the softest "homogeneous" metals, in which the percentage of carbon fell to one-fourth or less. The values of the required ratios were determined within this range for about thirty steels by Mr. W. R. Baird. As the writer had been led to suspect that the value was variable, and that it was some constant function of the total angle of torsion,* the values obtained were laid down on a sheet of profile paper, on which the ordinates represented the numerical value of the ratio obtained by the division of the tensile resistance in pounds per square inch of original section to the resistance of the standard test-piece in foot-pounds of torsional moment, while the abscissas were proportional to the total angle of torsion at the moment when the test-piece exhibited the maximum resistance as measured upon the autographic strain-diagram. The accompanying plate (XXII.) is a copy of that prepared as described. It is seen that the values thus recorded have a regularity which is probably quite as great as should be expected when the irregu-

* See Wood's Resistance of Materials, p. 204.

larity of structure of samples, due to causes apart from their composition, is considered. No pair of samples compared are ever of *precisely* the same character, either physically or chemically, and the ratio for samples cut from the same bar will therefore sometimes exhibit some variation.

Drawing a mean line through the group of determinations, it was found that it was approximately straight, *A B*, although probably really a parabola, *C D*, having one of its asymptotes not far from the height 200, but somewhat below it.

No determinations have yet been made for materials having maximum resistance at angles of torsion exceeding 300 degrees, and the law cannot therefore be traced beyond that point. As all the materials in general use in engineering attain a maximum within that limit, the law determined here is sufficient for all practical, if not also for all scientific purposes. Since the ratio varies, as is seen in the figure, inversely as the angle of torsion, it follows that so long as the molecular resistance to distorsion remains constant, the ordinate of the strain-diagram must diminish with increase of the angle of torsion. Uniform molecular resistance would thus be exhibited by a gradually falling line.

The equation for the ratio here studied, as determined from Mr. Baird's comparisons, is : $R = 300 - \frac{\Theta}{3}$, and $T = T^1 \ (300 - \frac{\Theta}{3})$; in which R represents the ratio and T and T^1, respectively, are the tenacity in pounds per square inch, and the torsional resistance of the standard test-piece* in foot-pounds of moment, and Θ the angle of torsion for maximum ordinate. This gives, for the standard diagram, a vertical scale, per inch of height, of $(30000 - 33{\cdot}33\ \Theta) = T$.

At the angle 150 deg., the scale, 25,000 pounds, is closely accurate. For nice determinations it is better to take a value two per cent. lower—24,500. It thus happens that determinations hitherto made on wrought-iron have been fairly, as they are now perfectly, comparable with those made by the old method.

It singularly happens that the commonly accepted theory predicts values of this relation which are not only incorrect but which are, for different cases, precisely the opposite in their mutual relations to those here given by experiment.

The value predicted by common theory is, for brittle substances, 250, and for ductile materials 188, the non-ductile substances giving the higher

* The standard test-piece for the autographic machine is 0.625 inch in diameter, and 1 inch long.

THURSTON—RELATION OF TENSILE TO TORSIONAL RESISTANCE.

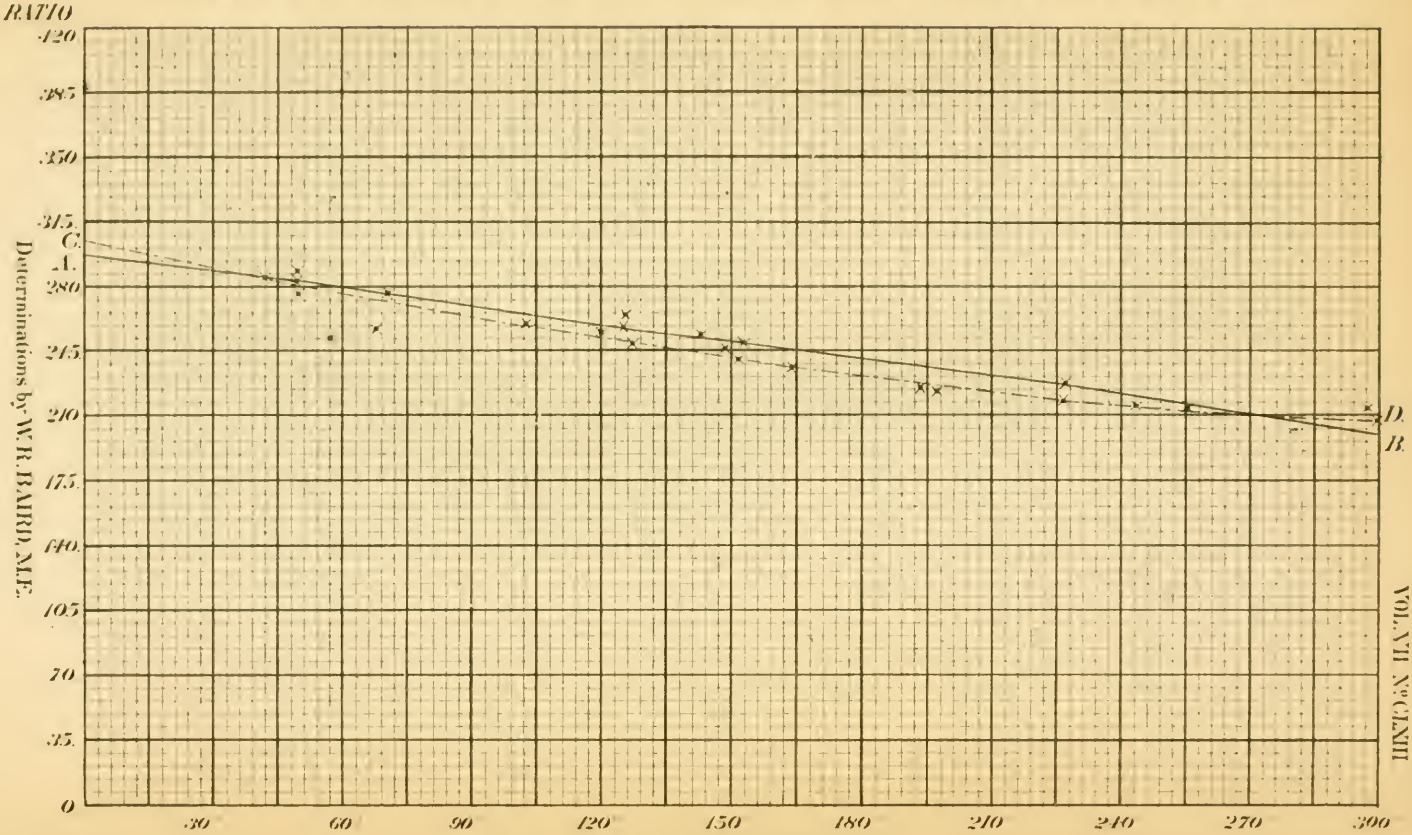

PLATE XXII
TRANS. AM. SOC. CIV. ENG'RS.
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value. But we have now learned that the latter class of materials, as represented by cast-iron give a value which is nearly, but perhaps slightly higher than that theoretically obtained for ductile metals: while the ductile class, as represented by the steels, give a value which is variable, but which, at the low angles of torsion at which they are comparable with the brittle metals, somewhat exceeds the values theoretically given for the latter, thus inverting the relation of these values as predicted by accepted theory.

The autographic strain-diagrams of which copies have been given in earlier papers by the writer, have usually had a vertical scale of 100 foot-pounds to the inch of ordinate. This is the scale now always adopted. For such diagrams, therefore, the vertical scale for tension will be, approximately:

For cast-iron..	20,000	pounds	per inch.	
For wrought-iron.....	25,000	"	"	at 150 deg.
For steels (rail).....	25,000	"	"	"
" " (tool).....	28,000	"	"	60

For other angles, the scale may be calculated as above where great nicety is demanded. Where the maximum ordinate remains constant in value, the upper part of the diagram becoming a horizontal line, the angle taken for measurement should evidently be that at which the ordinate first attains its maximum value.

The facts here detailed are, perhaps, insufficient to determine whether the singular and unanticipated relation revealed by them is due to some peculiarity in the method of action of torsional strain, or to the possible fact that those molecular modifications of cohesive force which produce a variation in the value of resistance to tensile stress, may produce variation in resistance to torsional stress in a different ratio. The indications seem to the writer to point toward the latter conclusion, and experiments upon the several grades of steel with a view to determining the effect of various chemical elements upon their strength and ductility, afford some ground for a similar deduction. Until this question is fully decided, the relation here revealed cannot be made a basis for a new and correct mathematical theory of torsion. It is hoped that, ere long, however, the needed facts may be supplied and that theory established.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CLXIV.

(Vol. VII.—July, 1878.)

OBSERVATIONS ON THE STRESSES DEVELOPED IN METALLIC BARS BY APPLIED FORCES.

By THEODORE COOPER, C. E., Member of the Society.

Read at a Meeting of the Society, July 17th, 1878.

While testing some steel links at the Keystone Bridge Works on June 26th, the writer accidentally noticed upon the link heads peculiar markings due to the cracking of the scale while under the test. A close examination of the lines convinced him that they were indications of the mode of transfer of the stresses about the pin-hole and throughout the head of the bars.

Careful sketches were made of all the lines upon the several sides of the heads.

Believing that the observations were entirely new and worthy of careful examination and study by those interested in physical phenomena, the writer has recorded all the data, and now desires to report the same.

§ 1. The links tested at this time were two in number. The material was steel, of the kind known as Hay's steel; having been made by a special process at the Edgar Thompson Steel Works as an experiment. By analysis of borings taken from the links, the carbon is 0.33%.

The links were forged from solid billets by Messrs. Hussey, Howe & Co., and sent to the above works for testing. The links were neither welded nor upset.

Test of No. 1 Link.—Section of body of bar, 3″×1″.1. Section of heads 7¾″×1″.2. Shape of heads as shown upon drawings.

Length from centre to centre of pin-holes, 2′ 9″—diameter of pin-holes, 3″—difference between pin and pin-hole, $\frac{1}{32}$″.

This bar was unannealed, being left to cool in same condition as when last worked under the hammer. Up to 40,000 pounds per □″ no permanent set was visible. At 43 350 pounds per □″, the scale commenced to fall off from the body of the bar. At 64 000 pounds per □″ (on body of bar) a bolt in the testing machine broke and the bar was removed. This accident brought to view the scale markings before mentioned.

Figs. 1 and 2 show the lines visible at this time upon the opposite sides of the head called *A* (for distinction); Figs. 3 and 4, those for head *B*. The pin-holes had elongated $\frac{3}{32}$ of an inch; the bar 5 per cent.

After recording the lines and other data, the bar was again placed in the machine and broken. It cracked outwards from the pin-hole in head *B* at a strain in body of the bar of 71 700 pounds per □″, showing a hard bright fracture.

From the appearance of the scale on this head and the fracture, the bar at this end had been overheated. The breaking through the pin-hole was, however, partly due to the distortion of the pin-hole under first strain and a want of care in securing a careful bearing upon the pin when replaced.

Figs. 5 and 6 show the lines visible upon head A after rupture of the bar. But few lines were visible upon head *B*, and these very imperfectly marked. The scale upon this head was coarse and uneven, and appears unsuitable for recording these lines.

Test of No. 2 Link.—This was a duplicate of No. 1, being of same dimensions and material, differing only in having been annealed by heating evenly to a red heat and then allowed to cool uniformly in the open air. No permanent set visible at 40 000 pounds per □″. After the

discovery of the lines upon No. 1 link, greater care was taken to observe the first appearance of them upon this second link. The result was exceedingly satisfactory and interesting, and the writer believes the key by which to interpret these lines was discovered.

The scale commenced falling at 45 700 pounds per □″. At 47 000 pounds per □″ distinct lines appeared upon a portion of the body of the bar. The strain was relaxed and the bar carefully examined. For about two inches the bar was distinctly marked with diagonal cross lines at 45° (as well as could be estimated by the eye) to the line of the bar. These markings were visible upon all four sides of the bar; the number of the lines being about 5 to the inch measured perpendicularly to the lines.

Fig. 7 represents the condition of the lines at this time.

On applying an increased strain, new lines appeared to the right and left of those which first appeared. As the new lines appeared, the old ones disappeared by the subdivision and disappearance of the scale.

The first appearance of the lines upon the heads of the link could not be observed from their position in the machine.

At 72 000 pounds per □″ the bar broke in the body at the point where the cross lines first appeared.

Stretch of bar =13 per cent.

Reduced section at points of rupture $= 2\frac{1}{2}'' \times \frac{2}{3}\frac{7}{2}'' = 33$ per cent. Upon both heads of this link, lines almost identical with those of Figs. 5 and 6, were visible, but not so distinctly marked.

§ 2. On considering these lines, the writer recalled to mind, having seen at a previous time eccentric lines about holes punched in steel plates, which he at that time thought were due to vibrations of the plate from the effects of the blow of the punch. These he has since re-obtained, and gives a representation of one in Fig. 8.

He has made, since the first discovery of those scale markings, many experiments upon specimens of steel and iron in order to investigate them. In iron he has not succeeded very well as the scale appears unsuitable. Various resinous coatings have been tried, but with only partial success. Upon one iron link (full sized bridge link, $5'' \times 1''$) he obtained a few lines at the four diagonal points of the link-head, corresponding exactly to those shown upon the steel links. This is his only success as yet upon iron. Upon steel specimens he has obtained quite a number. It appears to require a scale of a peculiar character; many

samples failing entirely, until the right scale is obtained. To avoid too many illustrations, a few sample sketches are given.

Fig. 9 is a compilation of lines obtained upon a number of grooved specimens of the form shown. Over a dozen specimens have been tested. No specimen showed all of these lines, but each one showed a portion. By combining such as were visible on the different ones, we have obtained Fig. 9. Those in the vicinity of the groove appear first at about 40 000 pounds per □″ on the grooved section; those about the pin-holes only at or near the rupturing point, which was usually from 89 000 to 95 000 pounds per □″ on grooved section.

Figs. 10 and 11 show a sample of lines produced by the shearing of a steel plate under a shear, one being from the top of the plate and the other from the bottom.

These lines are less definite in character than those from direct strains, undoubtedly due to the fact that the strains are very indefinite, being partly a shearing and partly a bending stress.

§ 3. It will be noticed from all these sketches that the lines appear in both directions, and cross one another at right angles. They are also at 45° to the line of applied stress in Figs. 7 and 8, where the *line of stress* is well determined. In the first case, being parallel to the direction of the bar, and in the second, on radial lines.

The writer thinks that it is also true that the direction of the transferred stresses upon the link-heads and in the grooved specimens are also at 45° to the markings. His reasons for so thinking will be expressed further on, as he desires to present his facts independent of all theories, and allow readers to take each, independent of the other, if they so desire.

§ 4. M. Tresca, before the Science Conference at South Kensington Museum, in 1876, states that while forging, on a large scale, some iridescent platinum, he noticed that "when the bar of platinum, at the moment of forging, had already cooled down to a temperature below that of red heat, it has happened several times, that the blow of the stamp hammer, which occasioned at the same moment, in this bar, both a local depression and a lengthening, heated it anew along two inclined lines, forming upon the sides of the piece the two diagonals of the depressed portion, and this reheating was so great that the metal along these two lines was brought back to a red hot temperature plainly enough for its form to be distinguished. These lines of greater heat

even remained luminous for several seconds, and presented the appearance of the two jambs of the letter X. In some cases we have been able to count simultaneously as many as six of these X's produced, one after another, as the bar under operation was being moved, in order to draw it out by degrees for a certain part of its length."

"The explanation of these luminous lines could not for an instant be doubtful: the lines of greater slip were, at the same time, the zones of greater developed heat." "If this fact had never been observed before, it was clearly owing to the circumstances necessary for its manifestation never having been all united together in so favorable a manner. Iridescent platinum requires for its deformation a large amount of work. Its surface is unalterable and almost translucent at a red heat; it is a medium conductor of heat: its calorific capacity very feeble; all conditions rendering the phenomenon visible in the case of forging platinum, while it has passed unnoticed in other metals."

M. Tresca afterwards was able to obtain similar results on other metals by coating the sides with wax, which was melted along these lines of slipping, when the bars were subjected to the blows of a hammer. It will be readily seen from this description that the lines thus obtained are perfectly similar in appearance to those shown upon Fig. 7.

§ 5. When a short prism of any material is subjected to a *compressive* force it *decreases* in length and *increases* in cross section until the strain is sufficient to produce rupture. In this change of form the upper and lower surfaces sustain but very slight enlargement, because they are prevented from spreading by reason of the friction at these bearing surfaces. Towards the middle of the prism the enlargement increases in such a manner as to produce a curved profile. If the prism be circular in cross section before being compressed, the cross sections will all continue circles, but of varying diameters as we approach the middle. If the original cross section be a square, the cross sections, after compression, will cease to be squares, and will become quadrilaterals with convexly curved sides. When the experiment is carried to the rupturing point, the prism is ruptured in one of two ways, either by a sliding of a portion of the prism along one or more oblique surfaces—a very common method in specimens of the metals, wood and stone—or by the prism splitting longitudinally into two or more pieces.

§ 6. When a prismatic body is subjected to a *tensile* force, it *increases* in length and *diminishes* in cross section up to the time of rupture. If the

body be perfectly homogeneous, the cross sections diminish from each end towards the middle, giving the body, longitudinally, a curved profile. If the original cross section be circular, all the cross sections will continue to be approximately circles. If the cross section was originally square, the cross sections will no longer be squares, but quadrilaterals, with concavely curved sides.

Upon rupture, the fracture will tend towards one of two forms, either square across the line of applied stress, or at an angle approximating to 45° to the line of applied stress. The latter is a very common case in steel specimens; almost perfect pyramids or cones being obtained at times. Even those specimens of steel which appear to break of squarely, show upon the edges the tendency to the angular fracture.

General Discussion.—From such observations as are given in the two preceding paragraphs, and from the familiar processes of drawing out of metals by blows of a hammer or the pressure of rolls, we see that the application of a force to a material body produces within the mass a motion, or tendency to motion, not only in the direction of the applied force, but one also at right angles to this direction.

This must necessarily be so if we assume the *volume* to be *unchangeable.* An assumption always made in hydrostatics.

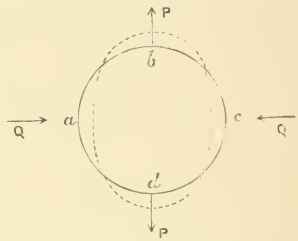
Usually it is considered that water is incompressible, but that the metals are compressible and extensible. This we believe to be a false distinction. They are all governed by the same general law—incompressible and inextensible—if by this we mean, as is considered in hydrostatics, that the volume or specific gravity is unchangeable for applied forces within the sensible limits.

This fact does not seem to have been generally recognized. The interesting results obtained by M. Tresca upon the flow of solids have now made clear the fact that the same laws govern the flow of solid bodies as the flow of liquids, the difference being one of degree only, due to the difference in the molecular forces to be overcome. Rankine defines "solids as bodies which tend to preserve a definite *size* and *shape.*" "Liquids those which tend to preserve a definite *size* only."

A *perfect* liquid, then, cannot be subjected to a *tensile* force on account of the want of molecular resistance to a change of form. It can only be subjected to a *compressive* force by resisting its change of form; for which purpose an equal resisting force must be applied in all directions;

whence follows the well known hydrostatic law of equal pressures in all directions.

Accepting the above definition of a solid, a *perfect* solid should be a body totally unchangeable in size or shape under any applied force. We know no such material. All known solids do change form under the smallest applied force, our ability to determine the same being only limited by the delicacy of our instruments of measurement.



§ 7. Any solid molecule, *a b c d*, subjected to a tensile stress, *P P*, elongates in the direction of the tensile force and contracts in the directions at right angles to the same, until the molecule assumes an oblong form, in which the applied forces and the molecular resistances are in equilibrium. Motion has taken place among the atoms in three directions—an extension along the line of the applied forces and a compression in two directions at right angles to these applied forces (one being perpendicular to the plane of the paper in above figure).

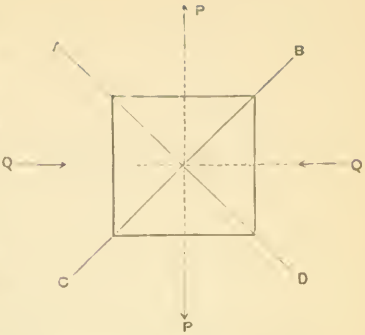
We can represent all the forces brought into action by three balanced resultant forces, *PP*, *QQ* and *RR*, at right angles to each other.

Similarly, for a compressive strain, we can consider *QQ* as the applied forces and *PP* and *RR* as the developed forces. To avoid filling this paper with mathematical demonstrations, the results of such investigations will be abbreviated from Rankine's Applied Mechanics, (referring those who desire to investigate the subject to Articles 111 and 112).

"A pull and a thrust of equal intensity on a pair of planes at right angles to each other are equivalent to a pair of shearing stresses of the same intensity on a pair of planes at right angles to each other, and making angles of 45° with the first pair."

If the pull and thrust be of unequal intensities, as is probably the case in most solids, the planes on which the shear is most intense, will still be the planes which make angles of 45°, with the axes of stress. The intensity, however, will now be an arithmetical mean between the numerical values of the principal stresses, or, in other words, one-half the algebraic difference of the stresses (giving opposite signs to stresses of opposite characters).

If P be the *intensity* of the pull, and Q the *intensity* of the thrust, the greatest shear will be upon the planes AD and BC, and its *intensity* will be $\frac{Q-P}{2}$ (P being a negative quantity).



§ 8. The lines of *greatest shear* or *sliding* should therefore be alongline at 45° to the line of applied force, as it is in Figs. 7 and 8.

In case of rupture by compression, this does not always hold true. For instance in cast-iron, the angle according to Mr. Hodgkinson, ranges from 42° to 32° for different qualities of cast-iron. Here, however, an additional resistance, not molecular, is to be considered, viz., the frictional resistance to sliding upon the plane of rupture, due to the normal pressure upon this plane.

Other causes, such as want of homogenity, unequal resistances to stresses of opposite kinds or to the same kind of stress in different directions, or slight variations from our assumption of invariability of volume may cause a failure of the theoretical expectation.

A homogeneous material, such as the several kinds of steel, upon which these tests were made, should under a tensile strain show the theoretical lines nearly perfect.

§ 9. *What then are these scale markings?*

If the preceding reasoning is correct, they are the *lines* of *greatest shear;* lines along which the metal slides to restore an equilibrium between the applied and resisting forces or *lines of flow.*

By a consideration of this tendency to flow or shear along diagonal lines, we can understand the changes produced in solid bodies by the action of applied forces ; whether such forces be applied by means of a testing machine, hammers, rolls or loadings upon our built structures.

From the investigations of M. Tresca, we are justified in classing all tangible bodies, as more or less liable to flow—the extremes being a perfect liquid and a perfect solid.

The element, *time* must be considered; for under a rapid application of force, the most ductile body may not have time to flow, and hence would relatively be less ductile than under a less rapid strain.

The form of rupture may also be explained by the same considerations.

§ 10. The influence of a groove in a soft or ductile metal has been noticed by all experimenters.

The breaking strain (measured on the section at the bottom of groove) being always higher than for prismatic specimens. On a hard non-ductile metal, there is no such increase.

By an inspection of the lines on Fig. 9, we see why this should be; the shear lines or lines along which the metal must flow, are much longer than they would be upon a prismatic specimen of the same cross section (see Fig. 7). A non-ductile metal, having no tendency to flow, would, of course, not receive this benefit.

The above applies only to statical strains or such as are usually applied in our testing machines.

In practical construction we seldom have purely statical strains; the strains are usually more or less suddenly applied.

For such suddenly applied strains the groove is an injury instead of a benefit; here, from the want of time for the principle of flow to come into action, the strain is all concentrated upon the least section and the ductility of the whole bar lost.

§ 11. If these principles be accepted (the writer feels that the data are too few to be too positive), can we not plot the lines of transferred stress from these markings by drawing a resultant line at 45° to the several lines of shear. Then to obtain a proper form, or a form of equal strength at all parts, cannot the transverse dimensions be so taken at all points that the shear will be uniform throughout.

The time which the writer is able to devote to a full investigation of this subject, being very limited, owing to his professional duties; and his desire to interest others in the investigation and discussion of the same must be his apology for presenting the subject in so crude and undigested a form.

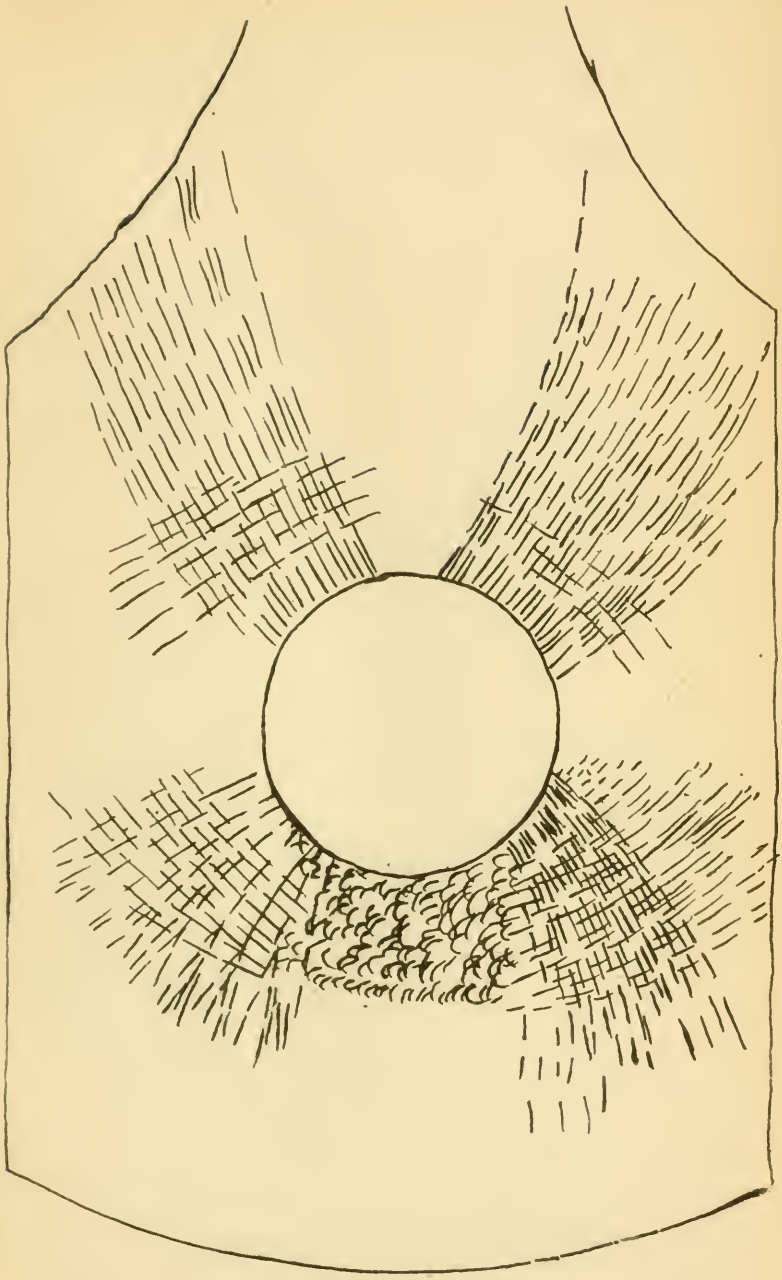


Fig. 1.

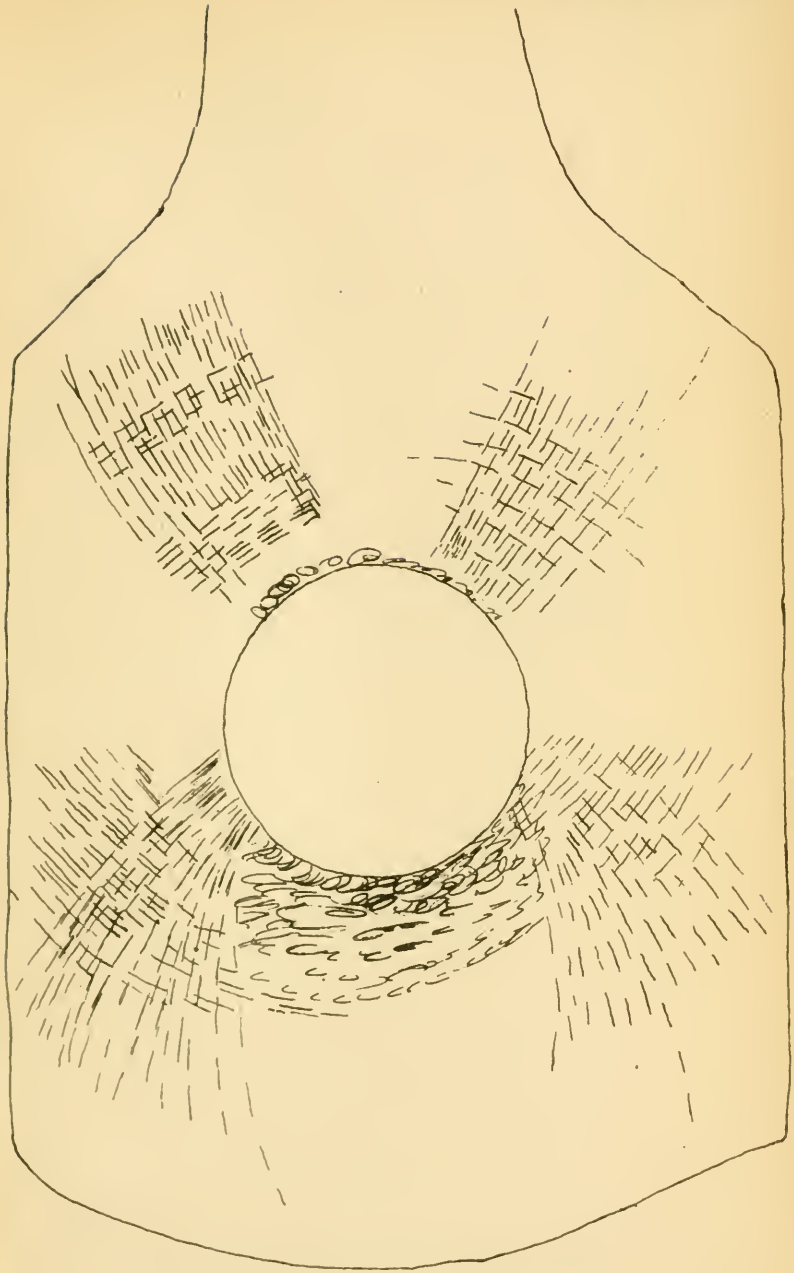


Fig. 2.

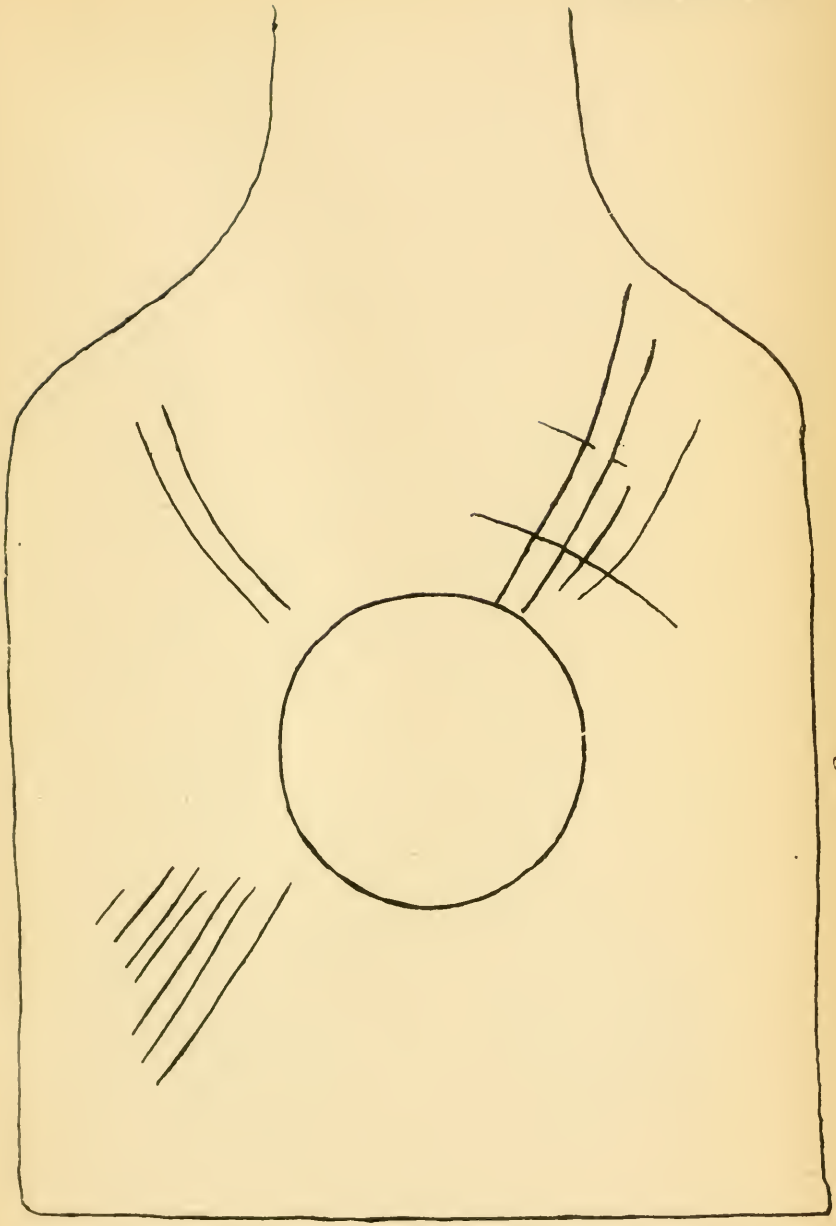


Fig. 3.

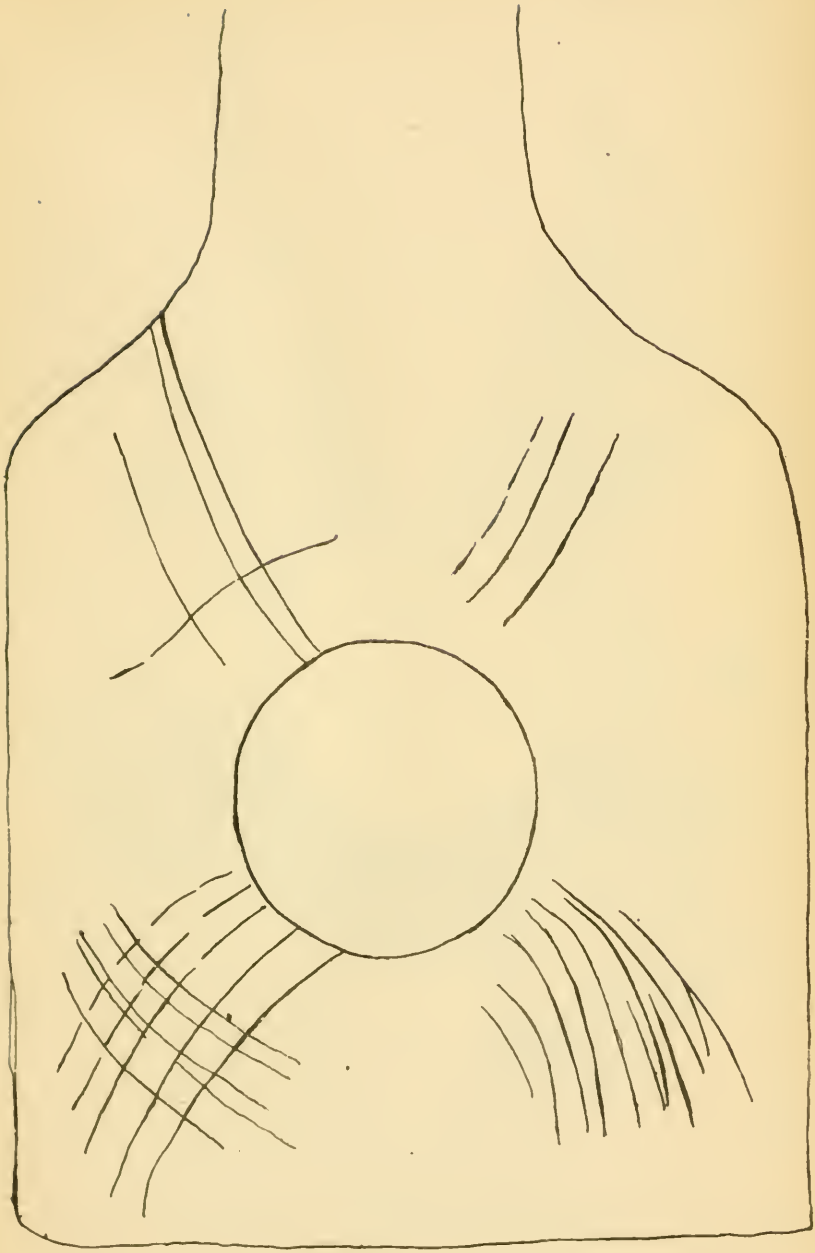


Fig. 4.

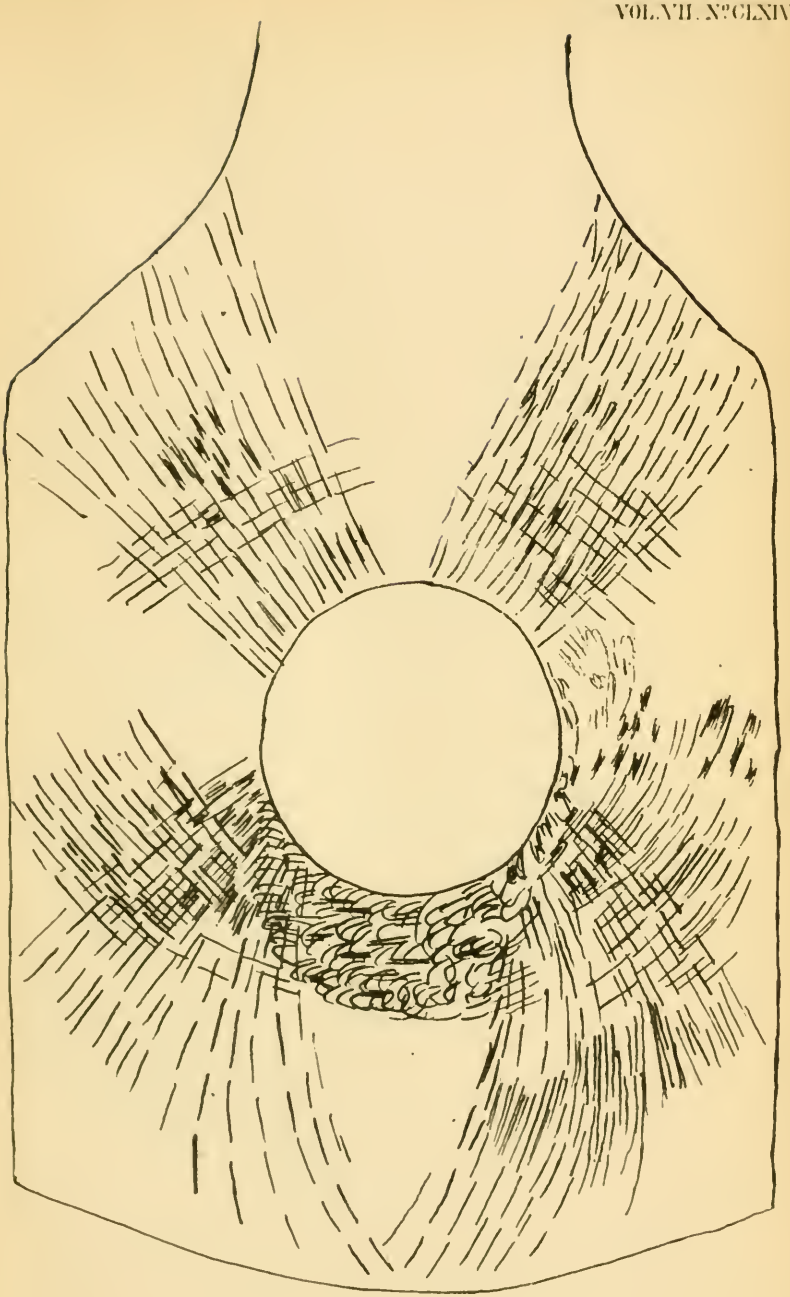


Fig. 5.

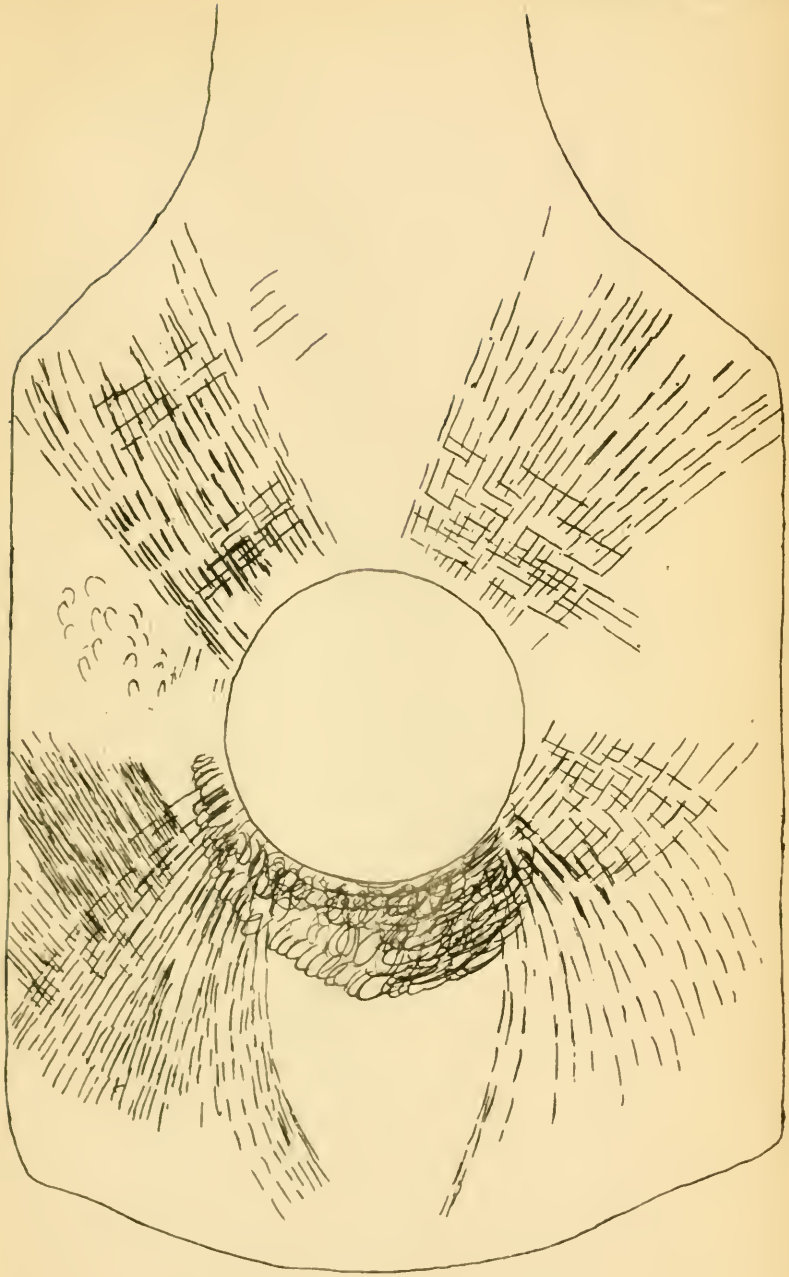


Fig. 6.

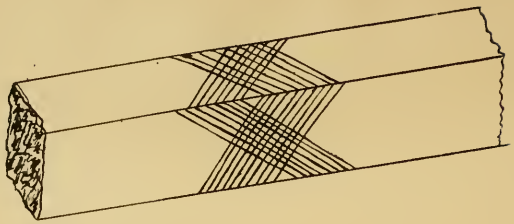


Fig. 7.

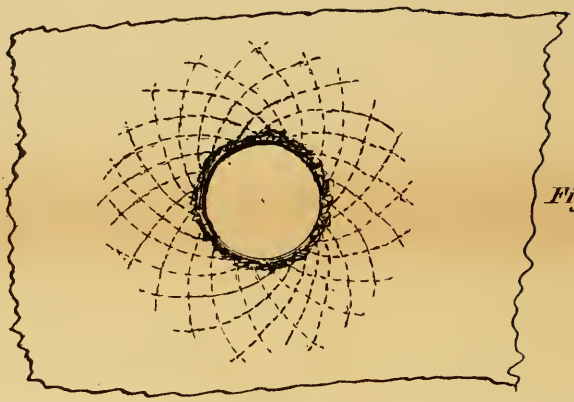


Fig. 8.

Fig. 9.

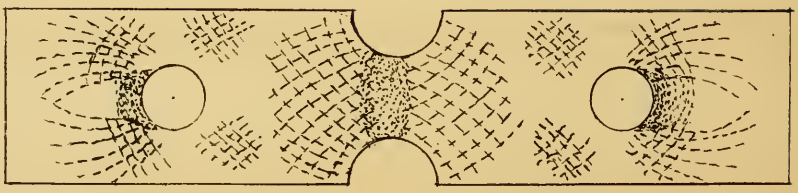


Fig. 10.

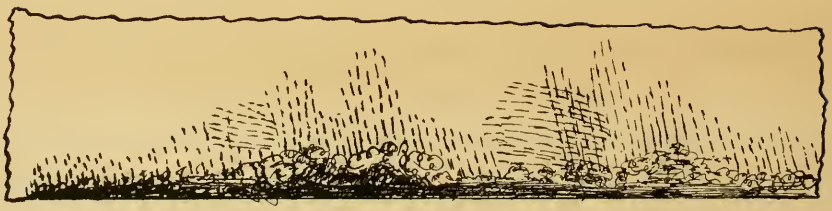


Fig. 11.

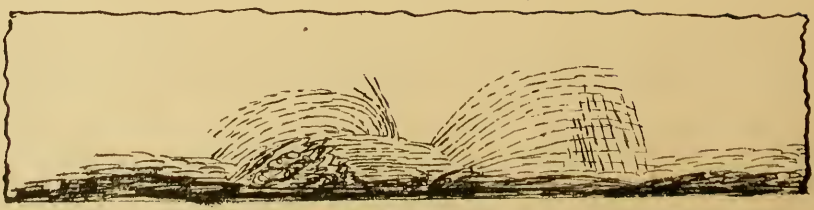


PLATE XXIX
TRANS. AM. SOC. CIV. ENG'RS.
VOL. VII. N°. LXIV.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CLXV.

(Vol. VII.—July, 1878.)

CUSHIONING THE RECIPROCATING PARTS OF STEAM ENGINES.

By JOHN W. HILL, M. E., Member of the Society.

This topic has already passed through a wide range of discussion by steam engineers and steam engine builders, and any effort to harmonize views variously entertained would probably be futile. It is, however, only of late years that the matter has been presented as a problem, many engineers and engine builders at the present time ignoring formulæ entirely, and resorting to the direct method of adjusting the cushion by experiment, that is, as in slide valve engines, the inside (exhaust) lap and advance of eccentric are varied until the motion of the engine satisfies the requirements of a smooth action. In setting the valves of engines similar to the Corliss, the method usually employed is to give the eccentric such an advance as will produce the desired lead, and then work up the action of the exhaust valves by the wrist plate rods until a smooth motion of engine is obtained.

Nearly all formulæ upon the subject of "cushion" presuppose conditions seldom found in practice, thus:

Absolute tightness of piston and valves.

Uniform counter pressure.

Uniform direct pressure, or pressure on steam side of piston whilst cushion is in process.

Uniformity of crank motion.

In addition to above, no note is made of the reduction of pressure in unjacketed cylinders by transfer of heat to the walls of cylinder.

All formulæ, so far as the writer is aware (excepting the elaborate demonstration of Charles T. Porter), deal with the motion of the piston as though it were uniform for similar positions in both half strokes. This, however, is an error, as the angularity of connecting rod causes the piston to approach and leave the inboard centre at the highest velocity.

The first objection noted is usually true of all new engines, and probably few, if any, operating engines are mathematically tight in piston and valve joints. If leaks exist, however trifling, corrections must be made in the adjustment of valve motion to compensate for the losses.

The lack of uniformity in counter pressure, even under the most favorable conditions, *i. e.*, uniform load and nearly uniform boiler pressure, as exhibited in the trials of automatic engines at the Cincinnati Industrial Exposition of 1875, is sufficient proof that a variable pressure must exist in the cylinder, when the load on the engine and pressure in the boiler are constantly fluctuating.

The lack of uniformity in pressure on steam side of piston at time exhaust closes is obvious, as the slightest variation in the pressure in the chest, or load on the engine, affects the pressure at every point in the stroke of piston.

The lack of uniformity in crank motion will be apparent when the action of regulator is considered. So long as the angular motion of crank is uniform, no change occurs in the motion of regulator. In the operation of the engine, however, at every half revolution of the crank the regulator revolves at several different speeds, hence uniformity of angular motion of crank does not obtain.

The loss of pressure by transfer of heat from the steam confined in front of the piston to the metal of the cylinder and to the liquefaction in the cylinder must occur when the temperature of the steam is augmented above the temperature of the metal and water.

Professor Rankine, in discussing the problem, suggests: "The most

advantageous adjustment of cushion takes place when the quantity of steam confined or cushioned is just sufficient to fill the clearance at the initial pressure."*

Mr. F. W. Bacon suggests: "The cushion should vary between one-half and the whole initial pressure, according to the speed of piston and action of valves."† What the maximum cushion pressure has to do with the *action* of valves is not clear. Perhaps the author means the action of valves determines the "grade" of cushion, which is true.

Mr. Charles T. Porter, in his admirable treatise on the Richards' Indicator, "proposes to adjust the cushion upon the weight and velocity of reciprocating parts."

Quoting from the printed circular of a celebrated engine company, the builders say: "There is a great advantage also in the great regularity of speed obtained * * * * by variable cut-off and variable compression." When it is understood that a variable cut-off controlled by the regulator will govern the speed within a range of *one-half* to *two* per cent., it seems singular that the builders would resort to variable compression, when it is not claimed that the regulation is thereby improved. This is one of those peculiar cases, however, where "the wise man makes a virtue of necessity." The valve used in this engine is a "balanced" single slide, the automatic regulator being attached to and revolving with the engine shaft, and the regulation is effected by advancing or retreating the eccentric through direct connections. Where variable cut-off is obtained by a single slide valve, any change in the function of "cut-off" produces a similar change in all the other functions, thus an early "cut-off" is accompanied by an early "release," and early "exhaust closure" with augmented "cushions," and *vice versa*. In this engine the peculiar arrangement of expansion gear is such as to make variable "compression" a function desirable or not. The builders, therefore, take a truly philosophical view of the situation, and enlarge on variable compression as a point of excellence. When it is considered that the weight of reciprocating parts remains the same at all speeds, that the velocity of piston is not permanently affected by changes in load or boiler pressure, that the direct pressure diminishes as the cut-off is hastened, it seems at least doubtful practice to employ "cushion" directly, in opposition to all theoretical deductions upon the subject.

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* Rankine on the Steam Engine, page 420.

† Bacon's Treatise on the Indicator, page 66.

The following investigation, although presenting no novel feature, may be interesting to members of the Society having to deal with steam engines. The writer would suggest that the demonstration "with no cushion" is entirely practical, as he has proven by many experiments that engines may be so operated without affecting the regularity or ease of action. In such cases the momentum of reciprocating parts is balanced by lead alone.

The reduction of economy by no "cushion," and the reduction of capacity by "cushion" to initial pressure will be exhibited.

Evidently, with no cushion, the full capacity of cylinder is realized in the power developed, whilst a loss of heat occurs, due to filling the clearance space with steam at initial pressure, the clearance being previously filled with steam at counter pressure; under these conditions, the absolute loss is the difference between the heat represented by the weight of steam filling clearance at counter pressure, and the same term at initial pressure; and the proportional loss will be this difference divided by the total heat expended per stroke of piston, thus $\frac{a}{A+a} = X$, when A = heat expended in producing the power independent of heat lost, and a = the heat lost by reason of no cushion. The cost of the power will be represented by the total heat expended per stroke of piston, divided by the dynamic effect of engine, thus $\frac{A+a}{H} = Y$ when H = the work done.

If the exhaust closure is early enough to bring the pressure of the steam confined in front of piston, up to the initial pressure, then no loss of heat will take place in filling the clearance with steam at initial pressure, as this has been obtained solely by compression. But the capacity of cylinder has been reduced by "cushion" to a certain extent. Theoretically there is no loss of power by this process, as the energy absorbed in "cushioning" the steam is given up again when the piston begins the opposite stroke.

The absolute reduction of capacity of cylinder is represented by the power expended in producing the cushion; the proportional reduction will be represented by a fraction with the mean pressure of cushion referred to total stroke for the numerator, and the mean pressure for whole stroke estimated from base lines as the denominator; let p represent the mean pressure of cushion for whole stroke, and P mean pressure for whole stroke, estimated from base lines, thus $\frac{p}{P} = X^1$ where X^1 repre-

sents the per cent. loss of cylinder capacity by full cushion. Let H^1 represent the power developed, and A^1 the heat expended in producing the power; then the cost of the power is represented by the fraction $\frac{A^1}{H^1} = Y^1$. Assuming useful expense of heat in both cases to bear a certain ratio to the power developed, which is probably true of the same engine, operated under like condition of boiler pressure and cut-off, then Y is evidently greater than Y^1, hence the cost of the power is least with full cushion. Again, as the dynamic effect of piston, with no cushion is based upon the mean pressure estimated from base lines, and the dynamic effect with full cushion is based upon the same pressure less mean pressure of cushion, it is also evident that H is greater than H^1, hence the maximum capacity of cylinder is obtained with no cushion.

To illustrate the preceding propositions, the following facts are assumed: cylinder, 22″×44″—revolutions, 70—effective vacuum, 20.66 inches—clearance, 1.75 per cent. of piston displacement. The diagrams upon which the calculations are based represent the average performance of such an engine, and furnish as a mean the following values:

Initial pressure	77.5	pounds.
Terminal pressure	12.125	"
Total mean pressure without cushion	31.133	"
" " " with "	28.000	"
Counter "	3.75	"
H P., without cushion	184.0	
" with "	165.6	

Estimating the temperature of water in hot well at 140, and the pressure of evaporation in the boilers as 80 pounds absolute, then the thermal units furnished per pound of steam become 1 068.8.

The expense of heat under first condition has been estimated as follows.—the piston displacement per hour to release (98.125 per cent. of stroke) was 79 781.05 cubic feet; volume of clearance per hour, 1 422.84 cubic feet: weight of cubic feet of steam at terminal pressure, .0316 pounds, and steam accounted for to release per hour 2 565.04 pounds; the exhaust closes at end of stroke retaining in the cylinder (per hour), 1 422.84 cubic feet of steam at counter pressure; the weight per cubic foot at this pressure is taken at .01048, and weight of steam retained becomes 14.91 pounds; net steam consumed per hour, 2 551 pounds; steam per indicated horse power, 13.86 pounds, and thermal units accounted for per I. H. P., 14 813.56.

The expense of steam under the conditions of full "cushion" has been calculated thus: Steam accounted for to release, as in first case, 2 565.04 pounds. In this case, the exhaust closes at 36 per cent. of stroke (from end), and the volume of steam retained in cylinder, including clearance, 30 692.82 cubic feet; weight of steam confined 321.66 pounds; nett steam consumed 2 243.38 pounds, and steam per I. H. P. per hour, 13.53 pounds. Thermal units accounted for per I. H. P. per hour, 14 460.86. The per cent. of saving by full cushion appears to be in this instance, 2.38, while the reduction of cylinder capacity to obtain full cushion is nearly 10 per cent.

The full "cushion" has been established by Marriotte curve drawn (on the diagram) from the pressure at beginning of stroke, to an intersection with line of counter pressure. The usual construction of engines, however, is such as to disqualify the Marriotte curve in approximating actual results; thus whilst in this instance the theoretical loss of cylinder capacity by full cushion appears to be 10 per cent. experiments upon the engine prove the loss much greater than this. In engines of the cut-off class, where separate valves control the "steam" and "exhaust," it is possible to obtain the best results; but with slide valve engines such as are in the majority, where a single valve controls the several functions of "lead," "suppression," "release" and "cushion," it is possible to obtain full cushion pressure only at a sacrifice of 15 to 50 per cent. of cylinder capacity, the largest loss usually occurring with engines having balanced valves.

The writer is of opinion that the cushion should be adjusted to realize the highest economy with least reduction of cylinder capacity.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

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DISCUSSIONS AT THE TENTH ANNUAL CONVENTION.

(*a.*) On Paper CXL.—The Determination of Stresses in the Eye-Bar Head. By DE VOLSON WOOD.

(*b.*) On Papers CXLIV and CXLIX.—Relative Quanities of Material in Bridges of different kinds, of various heights. By WILLIAM H. SEARLES.

(*c.*) On Paper CLVII.—Steam Engine Economy. By J. FOSTER FLAGG and E. D. LEAVITT, Jr.

DISCUSSION ON PAPER CXL.—The Determination of Stresses in the Eye-Bar Head.*

DE VOLSON WOOD.—What I have to say upon this problem will be of the most general character.

Some years ago I attended a Commencement Exercise, at which a celebrated Boston orator gave an address, in which he said: "Man is not placed here to do good, but to be good." The president of the institution followed, a few hours afterwards, in some remarks to the graduating class, and referring to this sentiment, said, in his peculiar tone and manner, "Gentlemen, the analysis is too refined." So I might say, in a general way, in regard to this analysis, "It is too refined." I do not mean, however, that it is the fault of the analysis; for in regard to that I will say that it is no more refined than the character of the problem demands. Professor Burr has made such thorough work with this problem that we are not disposed to take it up anew.

* Vol. VI, page 127. (May, 1877.)

In a general way, with regard to the effect of analysis upon the solution, practically, of problems of this character, a grand purpose is served in showing the limitations of the problems ; that is, they show that certain superior dimensions need not be exceeded, and certain inferior limits must not be discarded.

But the analysis is too refined, because the conditions upon which it is founded are not realized. For instance, it is necessary, in the first part of this problem, if we follow the analysis of the writer, to assume that the material is perfectly elastic, and that the stress at the rear of the pin follows that law of fluid pressure which causes the pressure to be normal to the surface at all points, Now, the material with which we have to deal is very gross. We may say, in a practical way, that good iron and good steel are very refined ; but the hypothesis of *perfect* elasticity may lead to results which are very far from being realized in practice. For my part I take but little interest in making an original solution of a problem of this kind, because I feel at the outset that I am obliged to make certain hypotheses in regard to the character of the stresses which may be far from the truth in practice, and that, consequently, the result which I may deduce will also be very far from being realized. Indeed I am sometimes surprised that the formulas which follow from the theories of Napier give results which we are enabled to use in practice. When I consider that materials are not perfectly elastic, that they are not homogeneous, that some of the materials to which the formulas are applied are not only practically but actually fibrous, I am sometimes surprised that the theory of elasticity, as applied to beams, gives results which we are enabled to use in practice. If the material of the eye was perfectly elastic and homogeneous, a trifling incident might change its character.

One day last winter a young gentleman from the room adjoining mine at the Institute, who assists in making experiments, came into my room and said : "Professor, look at this specimen." I said : "Well, what have you got here that is peculiar ? I see that you are attempting to make some experiments upon a piece of tubular iron," "Yes ; you see that it is drawn out here and is not drawn out there, do you ?" I said : "Yes, I do." From that we entered into some explanations in regard to what had taken place and what might follow. It was desired to make some experiments to test the strength of tubular iron, subjected to a longitudinal pull. To make these tubes they took solid iron and

drilled a hole along the axis of the piece. When they had got about half the length of the piece, the drill broke and stuck in the piece. To get it out they jarred it by knocking around on the outside of it with a hammer. Now the result was that directly opposite where the blows of the hammer were applied, it did not appear to change its form in the least; but just either side of that place, it drew down, and finally broke on one side. Now I say that if an eye-bar were perfectly uniform, and a few blows were made with a hand hammer on the metal opposite the eye on one side only of it, the two sides would not behave alike, and the side hammered would probably be the strongest. No workman is careful to make the two sides *exactly* alike.

He does not strike the opposite sides exactly the same number of blows, nor with exactly the same strength. He does not observe whether there is exactly the same amount of material placed on each side before he begins. Therefore the condition of uniformity cannot be perfectly realized.

In a communication to Professor Burr I made the following remark, which had a practical tone, if not a practical value: "That a theorist who from the results of his analysis, obtained a particular formula, felt better satisfied with his analysis if it gave results which agree nearly with those which have been established by practice. And I believe that that is the practical result of these investigations. I was not surprised to find, as was reported by Mr. C. Shaler Smith, in these Transactions, that different kinds of iron demanded different forms of eyes for economy and strength. These experiments showed that for some kinds of iron a semi-circular head, back of the eye, was the best form; while for other kinds the depth back of the eye should be from 1¼ to 1½ times the width across the eye, giving an elongated form to the outline of the eye.

We have noticed another important thing in regard to the distortion of this eye-bar—that, very much to the suprise of some, at the time the experiment was made, there was a heavy drawing in of the material, a little in front of the hole of the eye, producing a perceptible contraction in the width, notwithstanding the fact that the original width at that point was 1¼ to 1½ times the width of the main part of the bar. This part of the bar is not analyzed in Professor Burr's paper. He says it may be rounded off by an easy curve, etc. But it might be analyzed by making certain hypothesis in regard to the shearing stress.

Another feature of this class of problems may be mentioned. A cer-

tain kind of stress takes place at the rear of the eye, say a hoop tension; another kind opposite the eye which may be partly bending and partly shearing; another in front of the eye, which may be a shearing stress drawing the material in radially, or more strictly, transversely. It is impossible to so frame our analysis that we shall glide from one condition into the other. In order to analyze any portion of it, a certain condition must be assumed to exist throughout that portion; then if an adjoining portion is subjected to different conditions, the curves which bound the two must join when the two portions meet, if the problem is correctly solved. This is one of the theoretical difficulties which arise in problems of this kind.

Discussion on Papers CXLIV and CXLIX.—Relative Quantities of Material in Bridges of different kinds, of various heights.*

William H. Searles.—I had thought of adding something to the analytical considerations of these papers, or of presenting the same thoughts in an analytical rather than a graphical form, as the author has given them. But time has prevented my preparing anything of this kind, and I have only a single remark to make, which may be of interest to the Convention. I had occasion last year to put this problem to practical test. The bridges of the Erie Canal were originally designed mostly by our old and respected member, Squire Whipple, and generally with a very small height of truss. They are wooden bridges with parallel chords, and without counter bracing, unless sometimes in the middle panels. They wear out so rapidly, and especially in the lower chord, from dry rot and decay, due to the weather, that it was found profitable to put in iron lower chords, rebuilding the rest of the bridge in wood. But I soon discovered that the low truss required an excessive amount of iron in proportion to the rest of the bridge, and I took the liberty of raising the truss from a height of seven or eight feet, in a span of eighty or ninety, to sixteen feet, simply to reduce the cost of the iron chord—although, of course, there was some expense in additional wood used, and in the additional length of vertical rods. When this paper of Mr. Emery's appeared I subjected the case, with the given data, to this investigation, and found that the figures gave about sixteen feet as the most economical proportion, at the then prices of wood and iron,

* Vol. VI, page 235 (August, 1877), and page 277 (October, 1877).

respectively, and of the labor upon them. I then compared the cost of the sixteen feet truss, with the eight or nine feet truss, such as we had used, and found that, in a small bridge of a single roadway there was a saving of about one hundred dollars. The height of the bridge was objected to at first by the authorities in Albany, as apparently involving extra parts, and, as it was supposed, increased expense; but I was able to lay the figures before them in such a way as to make it perfectly clear that there was a great saving in raising an eighty or even ninety foot truss to the height of sixteen feet. Of course, it necessitated the counter bracing of every panel—not to resist strain, but simply to stiffen the long braces by giving them a central support, and a system of bracing overhead became necessary, which was entirely omitted in the low trusses. The bridge, as a whole, was very satisfactory, not only to the engineers who considered it, but to the people generally, and I was assured that there were no bridges which were crossed with a greater sense of safety than those high trussed bridges, which agreed very closely with the proportions given in Mr. Emery's papers.

Discussion on Paper CLVII.—Steam Engine Economy.*

J. Foster Flagg.—It appears to me that Mr. Emery has committed the same mistake in his formula for the value of D (Vol. VII, p. 61).

$D = \frac{1\,000\,000\,H}{T - t + .0013\,H}$, that I made in my formula for the efficiency of vacuum pumps, given in my paper on that subject,† which mistake I mentioned and corrected at the New Orleans Convention—viz., including in the denominator the term $\frac{H}{772}$ or $.0013\,H$.

This term indicates the amount of heat in the steam passing through the engine which is supposed to be consumed in doing the work; if the heat which is converted into work, were abstracted from the steam in the pump, this term would be very properly inserted in the formula, but, as is very clearly explained in Porter's "Treatise on the Richards Steam Engine Indicator,"‡ in vacuum pumps, or in any steam engine using steam for the full stroke without expansion, the work is done *in the boiler*

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* Vol VII, page 60 (March, 1878).

† Trans. Am. Soc. of Civ. Eng., Vol. V, p. 381.

‡ 3d Edition, Part four, Section one

by giving to the steam a greater number of thermal units. Even in engines whith cut off steam at some fraction of their stroke, a portion of the work is still done in the boiler, although with a very short cut-off, nearly all would be obtained at the expense of the heat in the steam enclosed in the cylinder ; so that this term would need modification for each engine working steam expansively, according to the degree of expansion.

This term is very small with the rest of the denominator, and but little error occurs from its insertion, or if correctly there, would be caused by its omission. Still, as a matter of theory, it seems to me that the formula to be correct should have this term stricken out entirely for non-expansion engines.

E. D. Leavitt, Jr.—I will not, at this late hour, detain the Convention by extended remarks on what is to me an interesting subject.

Mr. Emery's proposed basis of comparison commends itself by its simplicity and convenience.

In steam trials as usually conducted, on the basis of coal consumed, the quality of the fuel is an element of overshadowing importance, and it is possible for a comparitively inferior engine, if provided with a first-class boiler and the best of coal, to show a high duty.

By adopting the unit of heat as the basis, the engine is tested upon its own merits as an instrument for converting heat into work, and the percentage thus utilized can be readily determined, irrespective of the quality of fuel or efficiency of the boiler (as an absorber of heat).

On the coal basis, long trials are necessary because it is impossible to accurately estimate the relative value of the fires at starting and ending—the more widely these points are separated the smaller will be the error.

By weighing the feed water, noting pressures and temperatures at frequent intervals, maintaining the water level in boilers constant, and taking indicator cards near together, we have the elements for accurately determining the efficiency of an engine in a comparatively short run. A series of such trials, which can be made during the ordinary daily performance, is to my mind much better than the usual trials of forty-eight hours.

I hardly think it possible to test pumping engines accurately by the thermometric method proposed by Mr. Emery. Even if a special stirring apparatus were provided for mixing the water in the well with the hot well discharge, the mass would hardly have a uniform temperature for want

of time, and my faith in thermometers is very weak when it comes to fine measurements.

The dynamic head, by a mercury gauge at the base of the main, and the water actually discharged by the pumps, as determined by wier or other correct measurement, should be taken in computing the pumping engine duty.

Mr. Emery justly remarks that the means for obtaining economy in steam engines are well understood. This is a fact of long standing, and yet "one hundred millions" remains a very difficult achievement. Excellence of design must be supplemented by the highest practical skill and most conscientious fidelity in construction, if we are to make the last ten millions of the hundred sure.

The relative merits of compound and long stroke single cylinder engines are decidedly in favor of the compound if the same stroke, and type of valve gear be adopted. With a somewhat extensive experience in the construction and use of high speed of piston, high pressure steam and large measures of expansion (in single cylinders), I have found that as economical results were obtained when cutting off at one-fourth or one-fifth stroke as earlier; in fact, even with jacketed cylinders of small diameter and long stroke, the advantage was in favor of the later cut-off. Eighteen pounds of feed water per horse power per hour, is the best result that has come under my observation with this type of engine and in that instance there was some doubt as to the accuracy of measurement.

At the trial of the Corliss engines at the Merrimack Mills, Lowell, in 1877, the average results for one week were $19\frac{35}{100}$ lbs. feed water per horse power per hour, and I think it will be found difficult to exceed this economy in practice.

Mr. Emery's table shows that the compound engine of the "Rush," with the disadvantage of short stroke and ordinary valve gear used 18.384 pounds, and the Lawrence pumping engine but 14.019 pounds per indicated horse power per hour, which is $27\frac{1}{2}$ per cent. less than the Merimack Mills engine above referred to.

There is unfortunately a dearth of reliable experiments with the long stroke marine engines that have been cited as equalling the compounds in efficiency. In a recent number of "Engineering," the statement is made that some single cylinder Corliss Pumping Engines at the water works of St. Maud, near Paris, have run with $12\frac{1}{10}$ lbs. of feed water per horse power per hour. Until we have the data for computation in detail,

such statements will not be accepted as correct by engineers in this country.

In closing, I desire to call attention to the basis of comparison adopted by Prof. Cottrill in his admirable work, entitled, "The Steam Engine considered as a heat engine," viz., "Units of heat per horse power per minute," an elegant expression involving but three figures in the statement of performance of any engine exhibiting an efficiency of .05 and upwards.

ERRATA.

Paper CLXII, Vol. vii., June, 1878.

Corthell on South Pass Jetties.

Page 135, fifth line from bottom, change word *Northward* to read *Westward.*

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CLXVI.

(Vol. VII.—August, 1878.)

REMINISCENCES AND EXPERIENCES OF EARLY ENGINEERING OPERATIONS ON RAILROADS, WITH ESPECIAL REFERENCE TO STEEP INCLINES.

By W. MILNOR ROBERTS, C. E., Member of the Society.

Read May 1st, 1878.

My first acquaintance with railroad inclined planes began in Pennsylvania, at Mauch Chunk, on the River Lehigh, in the spring of 1827, whither I had been sent by Canvass White, chief engineer, as a young assistant to go upon the survey and construction of the Lehigh Canal. At that time Josiah White, of Philadelphia, was the acting manager of the Lehigh Coal and Navigation Company, and all the extensive works in and around Mauch Chunk were under his special charge. Erskine Hazard, his former partner, and one of the most active directors of the company, had previously, in 1826, visited Europe and examined the coal operations in England and Wales, and had also taken note of the very limited railroad experience of that day in England.

Having been personally familiar with the operations of these gentlemen during the years 1827–'28 and '29, and well acquainted with Josiah White, who then resided at Mauch Chunk, which was my engineering home for three years, I here take occasion to record that Mr. White was one of the most remarkable men of that period. His natural ingenuity was almost marvelous; which, joined to intelligent foresight and the most untiring energy and perseverance, enabled him to overcome engineering difficulties almost as quickly as they were encountered.

At the period of my arrival in Mauch Chunk Mr. White was engaged in changing the system of transporting coal from the summit of the Broad-Top Mountain (from the 60 feet thick bed of anthracite coal) by substituting a railroad for the turnpike. The turnpike was an admirable road, and so well graded that a large portion of it was used for the bed of the railroad then being laid. It was a gravity railroad, having a gauge of 3 feet 6 inches and a length of 9 miles. It terminated at the head of the inclined plane at Mauch Chunk, which was then in use for letting down coal to the "arks," in which it was conveyed by the then existing *descending* navigation on the Lehigh and Delaware rivers to the City of Philadelphia. On the Lehigh, Messrs. White and Hazard had constructed an artificial navigation, consisting of dams and movable gates, and the "arks" were *sluiced* from pool to pool for 47 miles, to Easton, on the Delaware.

While waiting for others of our engineer corps to arrive, and at intervals afterward, I saw much of this first American coal and passenger railroad laid down, and rode upon the first passenger train of very small cars which passed over it. I also paid particular attention to the working of the inclined plane. Having long ago unfortunately lost my notes and drawings of this early railroad, its cars, machinery, etc., as used in 1827, I can now only refer to them in a somewhat general way from recollection. The inclined plane had an elevation of about 200 feet. It was quite steep, especially at the ends, but flatter near the middle, conforming measurably to the slope of the irregular side hill. Its length was, I think, about three or four times its height. It had a double track passing place for the cars near the middle, a single track at each end, and was worked by the gravity of the loaded car, which, in descending, turned a large drum at the head of the plane, around which the rope was wound which pulled up the empty car, the motion being regulated by a friction brake.

During the summer or fall of 1827 Mr. White constructed another experimental inclined plane, upon a novel principle. It was of full size, and was worked by water power obtained from the creek which flowed through the narrow valley near its foot. The track itself was an ordinary 3 feet 6 inch gauge; but between the rails there were three movable wooden stringers the whole length of the plane, having upon their upper faces an iron rack. These movable bars were geared to the water-wheel so that they worked back and forth, alternately. To the rear end of the car three hanging bars of iron were attached, which touched and pressed their lower extremities against the notches or rack on the movable bars. When the water-wheel was set in motion, the car was pushed up the plane, in a rather jerking manner; the upward movement of each of the three bars progging the car along. I assisted in some of the experiments made with that very peculiar inclined plane. It certainly did fairly propel loaded cars up the plane; but the principle was not afterward applied at any time in the regular business of the company. All the old railroads and planes which existed at and near Mauch Chunk fifty years ago, the period referred to, have long been superseded by modern tracks of standard or 4 feet 8½ inch gauge for locomotives, and improved inclined plane gravity roads and switch-backs of the present era, which constitute such striking features of that coal region now. In 1827 the coal business of the United States and railroading were yet in their infancy.

In 1831 I was appointed senior principal assistant engineer under my friend and preceptor, Sylvester Welch, chief engineer on the Allegheny Portage Railroad in Pennsylvania. The other principal assistants were my lifelong friends, Solomon W. Roberts and Edward Miller, the latter since deceased, after a well-spent life. In the spring of that season I surveyed and located eight of the ten inclined planes, and afterward superintended their construction, namely, Nos. 3, 4 and 5 on the western, and 6, 7, 8, 9 and 10 on the eastern slope of the Allegheny Mountain.

Mr. S. W. Roberts, who had charge of the western half of the railroad, surveyed, located and superintended the construction of Nos. 1 and 2, the two planes on that division; which division included the first railroad tunnel in the United States. Mr. Edward Miller's duties began a little later, and they were chiefly in the main office with Mr. Welch, arranging the plans and drawings for the stationary engines and machinery of the ten planes.

The inclination of these planes varied from about 8 to 10¼ per cent. except No. 9, which was 7¼ per cent. The longest, No. 8, being 3,116 feet (including a very short curve at the top, and a curve 200 feet long at the bottom). It had a total rise of 308 feet, the straight portion having a rise of 10¼ feet per 100, or an angle of 5° 51′ 9″. The old Philadelphia and Pittsburgh turnpike, which crossed the mountain, in sight, and close by, had upon it grades of six degrees, and I made it a point, in establishing the inclination of the steepest plane on the railroad, that it should be flatter than the turnpike grade, and the fact was stated in our published reports following, for the information of the Legislature and the public. At that day there was a dread in the public mind in regard to inclined planes.

In 1832, in company with Chief Engineer Welch, I rode across the country on horseback, from the Allegheny Mountain, and visited the inclined planes on the Morris Canal, in New Jersey, and those on the Carbondale and Honesdale Railroad in Northeastern Pennsylvania, both being then new, and made notes and drawings to aid in the studies of the details of our mountain inclines. Mr. Archbald* was then chief engineer and manager of the Carbondale and Honesdale Railroad, upon which the inclined planes, with stationary engines at the head, had recently been put in operation.

Several plans were proposed for working the planes; the one adopted was with a double track railroad and an endless rope, worked by a stationary engine at the head of the plane.

No survey had been ordered by the State for a graded railroad without planes over the mountain. There had been, however, a survey made across the Allegheny Mountain, between Hollidaysburg and Johnstown, a distance of about 37 miles, in 1826, having partly in view a low grade *macadamized* road—the "macadamized" road being then a new thing in England. George T. Olmstead, under Canvass White, Chief Engineer, had charge of the survey; John T. Young, of New York State, was one of the levelers; F. H. Petrie, of Portland, Maine, was compassman; and A. B. Warford and W. Milnor Roberts were the rodmen.

Permit me in this place to mention the fact that Messrs. Clarke and Holgate made a survey in 1824, for a continuous canal through the Allegheny Mountain. In order to insure a sufficient natural supply of water they proposed a tunnel *four miles* in length. At that day such a

* The father of James Archbald, member of this Society.

tunnel became a subject of ridicule, and the canal project through the mountain was dropped. Yet Messrs. Clarke and Holgate were, like other bold projectors, merely in advance of the age.

The real impediment now, as it was then, is the fact that the *canal* would be frozen up, in this latitude, during at least one-third of the year. There is also another very important obstacle, the large amount of lockage—even with a four-mile tunnel.

In the State of Pennsylvania, a canal system, in preference to a railroad system, had been deliberately adopted in the Legislative Session of 1825–26, and Canvass White, then Chief Engineer of the Union Canal,* and prior to that one of the earliest engineers of the New York Erie Canal, was appointed to make the surveys between the Susquehanna river, at Duncan's Island, above Harrisburg, to the Ohio River, at Pittsburgh, by way of the Juniata river on the eastern side of the Alleghenies, and on the western side via the Conemaugh and Kiskiminitis rivers to the Allegheny, and down that river to its junction with the Monongahela, at the head of the Ohio, at Pittsburgh.

The State canals were begun in 1826 and 1827, but nothing was decided as to the mode of crossing the mountain for several years.

In 1829 preliminary surveys were authorized by the Legislature, and were made under the direction of Moncure Robinson,† for a railroad over the mountain, with inclined planes, between the terminal points of the canals—Hollidaysburg on the eastern and Johnstown on the western side.

In 1830 another set of surveys was made under the direction of Col. S. H. Long, U. S. A., and Major John Wilson—the latter was afterward Chief Engineer of the State Railroad between Philadelphia and Columbia.

These surveys indicated the employment of eleven inclined planes. Col. Long proposed several curved planes; but Mr. Robinson favored straight planes, even although some of them might cost considerably more.

After a partial examination of the grounds, in 1831, I suggested that it might be practicable to locate the line with five inclines on each side of the summit, all straight (dispensing with one plane), and Mr. Welch

* The Union Canal of Pennsylvania, 81 miles long, extends from Reading, on the Schuylkill river, to Middletown, at the Susquehanna river.

† Mr. Robinson, who is still living, was one of the earliest members of this Society.

instructed me to so locate them, if the cost should not prove too great. By the employment of short levels between Nos. 6 and 7, and 7 and 8, and making plane No. 8 considerably longer than the others, and with the maximum inclination of 10¼ feet per 100 feet, the location with ten instead of eleven inclines, all of them straight, was finally effected. At that early period in railroading the crossing of the Allegheny Mountain was regarded as quite formidable. Had the Legislature authorized surveys to determine whether a regularly graded road throughout or an inclined plane road should be adopted, it is possible that a road with inclined planes might never have been built there; but the general plan was, as already intimated, settled by the Legislature, in advance. A graded line would have been only about ten miles longer, even on a grade of $52\frac{8}{10}$ feet per mile, or about 47 instead of 37 miles.

It was not however, certain, when the Allegheny Portage Railroad was located (in 1831), that locomotives would be used upon it. After very careful surveys, at my earnest solicitation, a grade of $52\frac{8}{10}$ feet per mile for about three miles, on a straight track, below plane No 10, was adopted, in lieu of a line with numerous curves on a grade of $42\frac{24}{100}$ feet per mile. To bring the grade down to $52\frac{8}{10}$ feet, I had to sink it, at the foot of the plane, ten feet below the bed of the creek, put a culvert for the stream under the inclined plane, and excavate an entirely new creek channel for a considerable distance. It answered perfectly.

At that period there was a general impression among English engineers, assented to readily by our still less experienced American engineers, that locomotives could do very little work on grades above thirty feet per mile. There were then inclines of only 50 feet per mile in England worked with ropes and stationary machinery. Thirty feet per mile was the maximum adopted by Major Wilson,* the Pennsylvania State Chief Engineer, who located the first State railroad between Philadelphia and Columbia, 82 miles. Columbia is a town on the Susquehanna river, 12 miles west of Lancaster. The adoption of a thirty feet maximum gradient involved the construction of two inclined planes, one near Philadelphia, called the "*Schuylkill Inclined Plane*," the other at Columbia, called the "*Columbia Inclined Plane.*" They had inclinations of about 7 feet per one hundred feet rise. The Schuylkill plane was over half a mile in length (2,805 feet, with a rise of 187 feet). The Columbia plane was considerably less (1,900 feet, with a rise

* The father of W. Hasell Wilson.

of 90 feet). The intermediate line, about 78 miles, was located with the maximum grade of 30 feet per mile, and with numerous curves of 10° or over, deflection per 100 feet. The summit cut at the "Gap," east of Lancaster, proved to be so difficult and costly, on account of quicksand, that it was ultimately laid on a grade of about 44 feet per mile, and I believe it so remains.

The continuation of this State railroad from Lancaster to Harrisburg, 37 miles, was located by me as Chief Engineer in 1835, for the "Harrisburg, Portsmouth, Mt. Joy and Lancaster Railroad Company." I adopted a maximum gradient of 0.75, or $39\frac{6}{10}$ feet per mile, which was strictly adhered to in passing the summit, near Elizabethtown, Lancaster County. Some years afterward, when the Pennsylvania Railroad Company became the purchaser of the State improvements, they leased for ninety-nine years this Harrisburg and Lancaster line, and it now constitutes a link of their main line between Philadelphia and Pittsburgh.

In the session of 1847–48, the Legislature of Pennsylvania appointed me the engineer to survey and report upon a route for *avoiding the Schuylkill Inclined Plane.* At the time of this special appointment I was engaged in building the Sandy and Beaver Canal, in the State of Ohio, which was nearly completed. During the summer and fall of 1848 I made the survey and report upon the avoidance of this inclined plane, and recommended substantially the line upon which the new road (now part of the Pennsylvania Railroad) was soon after constructed.* I advised the sale of about three miles of the old railroad between the inclined plane and Broad street, Philadelphia, to the Reading Railroad Company, which was made. I also advised the purchase by the State of a large lot of ground on the west side of the Schuylkill river for terminal purposes; for this I was sharply censured by some critics for my extravagant assumption that so large an area could be needed. In those days they did not build terminal stations and round-houses, etc., by the acre. It would hardly answer now to confine the Philadelphia terminus of the Pennsylvania Railroad to twenty-five acres.

To return from this partial digression to the Allegheny Mountain Inclined Planes: the Mountain Railroad was finished, and a train of cars, drawn by horses on the levels, was passed over all the planes on the

* It may be here mentioned that the *Columbia Inclined Plane* was also avoided about the same time upon a route surveyed by W. H. Huffnagel, C. E., Assistant, so that about 1850 the State Railroad between Philadelphia and Columbia was freed from inclined planes and left with maximum grade of 45 feet per mile, and a general limit of 30 feet per mile.

21st of November, 1833. A committee of the Board of Trade of Philadelphia had gone out westward some time before, and we had promised to give them a pioneer ride over the Mountain Railroad on their return. We worked very hard, and barely accomplished it, much to their gratification. The train of new freight cars had been put upon the road by David Leech. They started in the morning from Johnstown, and about ten o'clock that night, in the midst of a snow storm, our friends, after passing over all the planes, were delivered safely in Hollidaysburg. The railroad and the canals with which it connected were then closed for the season. In the spring of 1834 the Allegheny Portage Railroad was regularly "opened to the public." It was so literally; for any persons who chose could put cars on the track, and haul them, with their own horses, from either end to the foot of the first plane, and on the levels between the planes; the State merely transporting the cars up and down the inclines, by means of the stationary engines at the head. This system, as the number of cars and of persons using the road increased, soon became exceedingly troublesome. I had the general charge and management of the running of the road, and of the inspection, weighing, numbering and registering of the cars during the season of 1834, as well as the general superintendence of the working of the ten inclined planes; so that I was almost constantly on the road.*

At the same time, the State having so determined, a permanent second track was being laid throughout the entire 37 miles, excepting upon the planes, where the track had been laid double in the first instance. This work, which was an arduous duty, was under the immediate charge of S. W. Roberts, Principal Assistant Engineer. A large number of cast-iron chairs were required for this road. They weighed from 13 to 14 lbs. each. The rail (excepting on the planes, where wooden stringers and flat bars were laid), was of the "edge" pattern, weighing 39 lbs. per yard. Added to my duties of that season was that of superintending the manufacture of the cast-iron chairs, and the delivery and acceptance of the chairs and rails, etc. The work of assistant engineers in those primitive days was only limited by their capacity. In the first track, stone-blocks 2 feet square and 1 foot thick were bedded on broken stone laid 1 foot deep, the blocks set at intervals of one yard from centre to

* During the season of 1834, I had the pleasure to escort M. de Cheyalier, of France, in company with Moncure Robinson, over the road. I also escorted General Bernard and his family at another time. General Bernard said to me that the Portage Railroad was second only to the passage of the Simplon in boldness and magnitude. Where are its glories now?

centre, supported the chairs, the chairs being fastened thereon by spikes driven through locust plugs 1½ inches in diameter let into holes 6 inches deep, previously drilled in the stone-blocks. The rails were held in place by wrought-iron wedges.

In the second track, in some places, stone cross ties 7 feet long were laid, at intervals of one yard from centre to centre, in lieu of the two separate blocks used in the first track. This, being bedded on a foot in depth of broken stone, made, as may be imagined, not only a solid, but a too *rigid* road. It may as well here be stated that in a few years these stone supports were superseded by wooden cross-ties.

The delivery of a large portion of the materials along the line for the second track, and for the duplicate stationary engines at the planes, added to the daily increasing general transportation of freight and passengers on the single track, demanded almost constant attendance on the line, as questions daily arose, in the use of the road by various independent parties, which I was daily called upon to settle. The "telegraph" was not yet born; and railroad experience was still a thing in embryo. The gigantic railroading of the present day had not then an existence even in dreams. Neither the "General Manager" nor the "Receiver," had yet been invented.

The machinery which worked the inclined planes was simple. An endless rope of from three to three and a half inches in diameter (for different planes) passed around a large horizontal, double grooved, fixed wheel at the head of the plane, and thence, supported on numerous sheaves, set in the middle of the tracks, to the foot, and around a *movable*, smaller horizontal grooved wheel below the foot of the plane. The lower wheel was attached to a carriage, so that when necessary, the slack of the rope, from stretching, was readily taken up. The stationary engines had double cylinders, of sizes proportioned to the particular plane. They were called from thirty to forty horse-power each. There were two systems of brakes for restraining the velocity of the rope and stopping the attached cars at pleasure; one, the ordinary iron-band friction-brake; the other, a water cylinder, having a regulating valve, which, when partly closed, checked the speed in proportion to the space left open for the water to rush through, which, when entirely closed, stopped all motion. I sometimes let a train (of four four-wheeled cars) down a plane by the water-brake alone, without using steam; and occasionally allowed a descending loaded train to bring up cars on the opposite track by their gravity, reg-

ulating the motion without the aid of steam, by the water-brake. The engines were high pressure, and were built at Pittsburgh and Blairsville. The ropes first used were hempen; though some grass ropes were put on during the year, which answered tolerably well.*

The freight cars were all four-wheeled, weighing from three to three and a half net tons each, or six thousand to seven thousand pounds. The passenger cars first used were of the primitive formation, designed and put upon the road by Mr. Lot Dixon, one of my assistant engineers. They seated comfortably twenty-five persons inside, and, like the interior of a modern street car, accommodated an indefinite number outside. We frequently "put the passenger cars through" over the 37 miles, including the passage of the ten inclined planes, in about five hours, and sometimes, under the most favorable circumstances, in four hours. The ordinary running time depended somewhat upon the extent of the delays caused by accumulations of freight cars. Upon one occasion, late in the season, I carried the business of the road, at Plane No. 10, when the stationary engine was out of order, by means of one of William Norris' locomotives, which weighed, I think, about twelve tons, by running it empty up the plane, and then attaching it to the endless rope on the descending track, putting on steam, and thus pulling up a train on the ascending track; then, detaching the locomotive at the foot of the plane, and again running it up. The same or a similar locomotive was run, by its own steam, up all the planes, including the steepest on the road, namely, 10¼ feet per 100 (541 feet per mile) for 3,100 feet of length, the total rise being 308 feet. The inclination of Plane No. 10 was 8¼ feet per 100, or 436 feet per mile; its length a little less than half a mile (2,295 feet). At the time the locomotive was run up the grade of 541 feet per mile, my opinion was that for a locomotive of that construction (with two drivers), 10¼ feet per hundred was *near* the limit at which it could be run up by its own steam power with only its own adhesion.

The grades on the so called "levels" between the inclined planes were very light, generally 0.40 per 100 feet, or 21.12 feet per mile.

At the planes the cars were attached (very quickly) to the main ropes by means of loose stopper-ropes—two to each car; the men specially employed for this duty soon acquired wonderful dexterity in hitching and unhitching; so that when there was no obstruction from accumula-

* A few years afterward, wire ropes, manufactured by my friend, John A. Roebling, C. E., were substituted, and were found to be in the long run safer and more economical than the hempen ropes.

tion of cars a train of four cars was passed up or down a plane with very little detention. In the first use of the planes occasionally a defective "hitch" led to the running away of cars, resulting in considerable damage. The Chief Engineer, Mr. Welch, suggested to me the employment of a small four-wheeled safety car, having a horizontal iron shoe, upon which the wheels of an accidentally detached car should be stopped, the car by its weight on the shoe producing sufficient friction on the rail to stop it on the plane. Upon reflection, it occurred to me that by using only two small wheels, with a bent axle, high enough to pass above the main rope, a very much lighter and much more easily handled car could be obtained. I accordingly made the drawings and had one built under my own superintendence in Johnstown. It was then tested on Plane No. 1 by allowing a car loaded with pig-iron to strike upon the shoes after a free run of some feet, when the car was at once safely stopped. This style of safety car was immediately adopted, and they were soon used, invariably in front of the descending and in rear of the ascending trains. The general plan was also copied and introduced on the other State inclined planes, at Columbia, and near Philadelphia. Accident from the breaking of the hitches or of the main rope were thus rendered comparatively harmless.

There was an incident at Plane No. 10, the lowest on the eastern side of the mountain, which may not be uninteresting, though it was only a troublesome *bore* at the time. The head of the plane was a very dry mountain spur, nearly two hundred feet above Blair's Gap Run, a mountain stream flowing nearly parallel with the spur upon which the inclined plane was built. The geological formation of the spur is a very compact dry slate rock, pitching into the hill at an angle of some thirty degrees. Flowing water could not be brought to this plane for the use of the stationary engines at its head short of laying pipes for nearly two and a half miles, and the conveyance of water by tanks up the plane becoming troublesome, a well was sunk a few feet deep at the head of the plane, and then a five-inch bore hole was started and sunk more than two hundred feet, that is, some feet below the level of the creek, without meeting with a drop of water. I then urged the laying of wooden pipes (of young hemlock) from a point on the creek high enough to allow the water to flow by gravity to the head of the plane. The chief engineer authorized it and it was done immediately ; but he also required the boring at the well to be continued, and it was continued to the depth of between seven

and eight hundred feet without encountering any water, excepting what we poured in at the top to assist the drilling. It was then abandoned. It affords good geological proof that the compact slate rock continues to that depth; and also that there is such a thing as an absolutely dry well, nearly eight hundred feet deep.*

In 1835, '36 and '37, being engaged in the building of the Harrisburg and Lancaster and the Cumberland Valley Railroads, in Eastern Pennsylvania, I had no direct connection with inclined planes, excepting that, in 1836, my friend William Norris invited me to meet a number of gentlemen to witness a promised performance of one of his locomotives, namely, to take a passenger car (eight-wheeled†), with fifty persons in it, up the Schuylkill Inclined Plane, at the rate of ten miles an hour. The first morning this experiment was to be tried it was found that some malicious or humorous individual had greased the track, which prevented the test for that time, but shortly after, when the grease had been removed, his locomotive actually performed as he had promised. A careful record of the performance was printed in a quarto pamphlet at the time, but I have not seen it for a great many years. One of the passengers was an English officer, who (as Mr. Norris afterward told me), when he related the occurrence in England, was not credited, the railroad *savants* on the other side having already "decided" that the limit of locomotive possibilities stopped very far short of 422 feet per mile rise, which was the grade of the Schuylkill Plane. The length of this plane was about half a mile.

In 1836 Mr. William Norris built several locomotives for me, to be

* On the first of January, 1835, an exceptionally cold day, I rode on horseback, in company with Chief Engineer Welch, from Johnstown to Blairsville, to meet James Clarke, President of the Board of Canal Commissioners, for the purpose of resigning my position on the Allegheny Portage Railroad, and of bidding him farewell. I had no further connection with that road till the winter of 1838-39, when the Board of Canal Commissioners appointed me their engineer to examine and report upon its condition, and to estimate the cost of putting it in thorough repair, which I did in the winter of 1839. The wire-ropes put in by Mr. Roebling were then in use, and were considered more economical than the hempen ropes. The same rails which had been laid down in 1833 were still in very good order, and the business had very largely increased. The Pennsylvania Railroad had not yet been seriously thought of.

† Passenger cars with eight wheels had not then been long in use. I think it was in 1835 that I went with Mr. Norris to Mr. Imlay's car shop, on Bush Hill, Philadelphia, to examine the first eight-wheeled passenger car, as I understood. I pronounced it just the thing for the Columbia Railroad, which abounded in curves. Mr. Imlay remarked that I was the first civil engineer who had said it would succeed. It was soon after placed upon the Columbia Railroad. I had the honor to have a similar car, which was placed on the road the same year, named after me by the authorities in charge of the road, without my knowledge or saying by your leave. Eight-wheeled passenger cars, in those days, were regarded as grand affairs.

used on the Cumberland Valley Railroad, between Harrisburg and Chambersburg, 51 miles, which road was opened in 1836–'37. One of them, the *Nicholas Biddle*, continued running until within a very few years. I think it ran thirty-eight years. It had only two drivers, about five feet diameter.

After the Pennsylvania Railroad Company had built their road over the Allegheny Mountain, only two miles north (at the summit) of the old Allegheny Portage Railroad, already described, with a ninety-five feet per mile grade between Altoona and the summit, near Gallitzin, and when the Portage Road, with its ten inclined planes, had been in use about twenty years, the Legislature of Pennsylvania directed surveys to be made to ascertain the feasibility of a graded railroad between Hollidaysburg and Johnstown. Robert Faries, C. E., who was then in the service of the State, made that survey, and reported it to the State authorities; whereupon the Legislature appointed, by name, Edward F. Gay, C. E., Robert Faries, C. E., and myself, a commission to examine, not only that route, but also the old Portage Railroad, and to report upon the advisability of retaining all or some of the inclined planes, or, of adopting a graded line, avoiding all the inclined planes. After examining, we were unanimously of opinion that it was better to abandon all the inclined planes and adopt the general line which had been surveyed by Mr. Faries, having a maximum gradient, on the eastern side, of seventy-five feet per mile, and on the western side of fifty-two and eight-tenths feet per mile; and, at the request of the other members, I wrote the report at Altoona, upon which the Legislature ordered the immediate construction of the graded road, which was then at once constructed under the superintendence of Mr. Faries.

This new State railroad and the Pennsylvania Railroad crossed the summit of the mountain within about half a mile of each other; the latter being the furthest north, and both having summit tunnels on the eastern approaches, the Pennsylvania Railroad tunnel being 3,750 feet, and the State tunnel 1,850 feet long. The two roads are in sight of each other for several miles east of the summit, occupying opposite sides of a deep, romantic gorge; while on the western slope of the mountain they were for miles laid side by side, both passing down the Valley of the Conemaugh, to Johnstown.* Few travelers who view the beautiful scenery

* At the time that the above Commission were engaged in examining the questions submitted to them, I received a letter from my friend J. Edgar Thomson, President of the Penn-

of this part of the Allegheny Mountains are aware that there are two important railroads, now dead, almost in sight.

Soon after the completion of the new graded railroad over the mountain, built by the State, and the abandonment, excepting at a few points, of the once famous "Allegheny Portage Railroad," the public works of Pennsylvania were sold, and the Pennsylvania Railroad Company became the owner of all the State railroads and canals between Philadelphia and Pittsburgh.

That company shortly after abandoned the use of the new State railroad, took up its excellent rails, and transferred them to the Pittsburgh, Fort Wayne and Chicago line; and thus ended the last vestige of State railroad operations in Pennsylvania. I therefore literally attended at the birth of Pennsylvania State railroads, assisted them in their youth as well as in their mature growth, and witnessed their final obsequies; all in a period of about twenty-five years.

In the fall of 1857, I was invited to visit Brazil to examine the "Dom Pedro Segunda Railway," for the purpose of offering proposals for its construction across the "Sierra," back of Rio Janeiro. I sailed in December of that year, and arrived there in January, 1858. In May, 1858, in company with five other gentlemen, all of the United States, I closed the contract, in the City of Rio Janeiro, with the "Dom Pedro Segunda Railway Company," for the construction of their road.

That road, at that time, was regarded as the most difficult and expensive railway of the period; though since then more difficult and more costly works have been projected and carried through in Europe, and some with even bolder features have been constructed on the Pacific coast of South America. The limit of grade and curvature adopted on the Dom Pedro Segunda Railroad was the same as had been used on the Pennsylvania Railroad in crossing the Allegheny Mountain above Altoona, namely, ninety-five feet per mile on tangents, and curves of eight degrees deflection per hundred feet. This limitation in the case of the Dom Pedro Segunda Railway, with the very rough topography of that

sylvania Railroad Company, to the effect that that company was then entertaining serious thoughts of building an *inclined plane* railroad over the mountain, *for their freight business;* under the impression that it would be cheaper to transport freight that way than by their graded road. It is of course a question for discussion. Our calculations at the time, however, showed that the State could transport cheaper on the graded road having a maximum grade of 75 feet per mile than it could on the road with inclined planes. At that period the State and the railroad company stood in the attitude of *rivals* for the great trade of the West passing over the Allegheny Mountain. There is, or should be, a history of the sale of the public works of the State; but it does not properly belong here.

region, involved a large amount of very heavy work, deep granite rock cutting and very high fills. There were thirteen tunnels in the space of nine miles of the mountain division, one of which, at the summit, was seven thousand two hundred feet long; another nearly half a mile, the residue shorter; making together three and a half miles of tunnel in nine miles of line.

About the year 1863–64, the road being well advanced on the eastern or ocean side of the mountain, and considerably forward on the western or Parahyba Valley side, it became obvious that time and money might be saved to all parties by the construction and use of a temporary track around the *Tunel Grande*, or "Big Tunnel," as we Americans called it; and the railway company consented to allow the sum of about $125,000 toward building such temporary road. It was accordingly constructed, with maximum grades of about 238 feet per mile, with curves of only 230 feet radii. The summit of the mountain which had to be surmounted was about 500 feet above the grade of the railway at the eastern portal of the Big Tunnel. The length of the temporary track was about five miles, three of which were on the eastern, and two on the western side. This track was used more than two years, during which a large amount of material, including the iron rails for the western side of the main line, was carried over; and much freight, especially coffee, and many passengers were daily transported upon it; and no accident ever occurred.

The locomotives were built by Baldwin & Co., of Philadelphia. They were Moguls, and weighed 42 tons each. They turned the curves easily, and usually took over a baggage car, an eight-wheeled American passenger car, and four or five large four-wheeled freight cars. They were limited to a slow rate of running, about five to six miles an hour; though they could have run somewhat faster, had it been desirable; but absolute safety was deemed an essential element in the management of a great and novel work among a people who were yet unaccustomed to railroads; many of whom persisted in declaring that they "would *never ride under the Sierra* through the Big Tunnel!"

It may as well be stated that although a chartered company intervened between the contractors who were building the railway and the Government of Brazil, the government itself was the real party. The government guaranty of seven per cent. per annum interest, made the stock worth several per cent. above the par of gold in the British market, and it was well understood that on the completion of the railway the government would take possession and run it, which it did.

The Emperor, "*Dom Pedro Segunda,*" whose name the railway bears, was not one of that class who entertained any apprehension about riding through the Big Tunnel; although at that period he had not visited Europe.

[Recently the people of the United States and of the principal countries of Europe have had opportunities of seeing what manner of man the Emperor of Brazil is—intelligent and studious, yet full of energy and life, quick to perceive, and remarkably ready in the comprehension of all improvements calculated to elevate the standing of the Brazilian Empire.]

During the progress of the railway works the Emperor visited the line several times in person, riding, wherever it was practicable, on horseback or muleback, and walking where it was otherwise, in tunnels, etc., and critically inspecting every part, and asking very practical questions. Without the slightest hesitation he descended, in the ordinary cage, the wet shafts of the *Tunel Grande*, 340 feet in depth. When the time came for blowing away the last remaining barrier of rock—only three or four feet thickness of granite to open a continuous passage through the main tunnel, the Emperor was there; he walked up to the solid face, listened to the sound of a hammer on the other side, saw the drill-holes, which were loaded and partly loaded, and then, stepping back a few hundred feet behind a safety barricade, awaited the firing, which a few minutes later took place; and the Emperor was the first man to pass through the space which the blasting had made; the writer following closely, accompanied him through to the other side, where we met and were assisted over the débris by Mr. Boyd, the manager of the western portion of the tunnel; the whole party then walked through the temporarily illuminated tunnel to the western portal. This was not so grand a display as that which took place a year or more later, when the imperial train of cars inaugurated the final complete opening; but it served to show most strikingly the very practical character of the Emperor.

The temporary track over the mountain was used for a considerable time after daylight first shone through the tunnel; for very much still remained to be accomplished inside. Strange as it may seem, this granite mountain, where it was highest, about five hundred feet above the tunnel grade, instead of being very solid, as it had been anticipated it would be in the line of the tunnel, consisted of very wet, partly decom-

posed granite, subject to heavy caving and sliding, and requiring a large amount of stone arching and side walls. This delayed the completion and augmented the cost. The entire construction, including the sinking of the four working shafts, occupied about seven years. The credit of the admirable management of this difficult tunnel work belongs chiefly to Jacob Humbird, now of Cumberland, Maryland. Mr. Humbird's earliest tunnel experience, when he was a very young man, was in connection with the first regular railroad tunnel in the United States, already referred to, in 1831, on the Allegheny Portage Railroad, as a foreman.* Afterward he had large experience upon tunnels on the Baltimore and Ohio Railroad, under Mr. B. H. Latrobe, C. E.

On the Baltimore and Ohio Railroad, upon which Mr. Latrobe was so long its distinguished chief engineer, the experience in the use of heavy inclines on temporary tracks was much more complete than any with which I had personal connection, or than has occurred anywhere else, so far as I know, where freight and passengers have been regularly conveyed by locomotives. Until it was mentioned by a member at the last meeting I was not aware that a portion of the grade on the temporary track at Kingwood Tunnel, on the Baltimore and Ohio Railroad, was so great as 10 feet per hundred, or 528 feet per mile. I had been under the impression that the heaviest grade on the Baltimore and Ohio Road, where steam had been used, was at *Parr's Ridge*, only about 360 feet per mile.

I have since seen a printed copy of Mr. Latrobe's admirable paper on the subject—which he kindly sent me, and which was published in the *Railroad Gazette* of December 5th, 1874, which gives, in the clearest manner, all the particulars, with maps and profiles of the main line, both at "Kingwood" and "Board Tree Tunnel."

I may be permitted to quote a few points. In regard to "Parr's Ridge," Mr. Latrobe wrote, referring to Kingwood and Board Tree Tunnel grades:

"The occasions referred to were not indeed the first upon which loco-
" motives had ascended steep inclines, for one of the little 8-ton grass-
" hopper engines of the Baltimore and Ohio Railroad has mounted and
" descended the original grades of that road across Parr's Ridge (one of

* That tunnel was constructed under the immediate charge of Mr. S. W. Roberts, C. E., as principal assistant under Mr. Sylvester Welch, C. E., the Chief Engineer. It was 901 feet long and had a double track through it. It was 25 feet wide.

"which was 360 feet per mile, since superseded by one of 82 feet). An "engine of some 10 tons, built by the late William Norris, had also "ascended the old Schuylkill inclined plane near Philadelphia, and no "doubt those experiments upon a small scale encouraged those upon a "more extended one of which I have given the preceding account."

The letter of Mr. Latrobe, just mentioned, is the most interesting, complete and satisfactory presentation of experience on steep inclines used by locomotives that I have ever seen. It should be read by every member of our Society who feels interested in this particular subject.

"At Kingwood Tunnel, on the Baltimore and Ohio Railroad, the top of the ridge was 210 feet above level grade of road at east end of tunnel. Temporary track on the east side reached summit in 3,400 feet. Grade first 2,200 feet, not uniform—steeper at first, then more moderate, till 90 feet height attained; average, 216 feet per mile. Remaining 1,200 *feet distance* and 120 *feet height*, 528 feet per mile, completed in a curve of 180 degrees, with a radius of 300 feet and 400 feet."

A grade of 1 in 10 on a curve of only 300 feet radius requires greater power to overcome gravity and friction than one of 10¼ feet per 100 of straight track.

The average ascent of the whole 3,400 feet, on the east side, was at the rate of 336 feet per mile, but the test of the power of the locomotive was on the "1,200 feet length of 1 in 10 grade, on a radius of 300 and 400 feet."

Look at the work performed:

An engine of 28 tons (56,000 lbs.), tender 34,000 lbs., car of iron and other materials at 30,000 lbs.; total 120,000 lbs., or 60 tons of 2,000 lbs. taken up a grade of 528 feet per mile, through a curve of 300 feet radius. "The grade and curvature on the west slope were much lighter than on the east slope; falling 305 feet in 7,000 feet; averaging 1 in 23, or about 230 feet per mile."

Mr. Latrobe states that the steep grade was used about two months in 1852; and that afterward an improved temporary line track reduced the grade from 528 to 230 feet per mile.

At "*Board Tree Tunnel*," Mr. Latrobe describes another "temporary track, having a grade of 1 in 20, or 264 feet per mile, overcoming 328 feet; with two switch backs on the east and five on the west side. Maximum grade 6 feet per 100, or $316\frac{8}{10}$ feet per mile, other reaches 4 feet per 100, or 211 feet per mile. Engine 56,000 lbs., tender 34,000

lbs., *two* loaded cars 30,000 lbs. each; total 150,000 lbs., or 75 net tons. When pressed, another car could be added, and still another."

Mr. Latrobe, in his able paper, refers also to a pamphlet published by the late Charles Ellet, C. E., in 1856, entitled "MOUNTAIN TOP TRACKS."

Since this paper was read before the Society the profession of civil engineers has been called to mourn the death of Mr. Latrobe.

Mr. Latrobe, very shortly before his last illness, mentioned to the writer that he had promised to prepare an article embodying some of his early engineering experiences, to be published in the "Railroad Gazette." His death has therefore deprived the profession of "experiences" which would doubtless have been interesting and valuable.

There are some of our older engineers yet living, who might confer benefit by gathering together and publishing for preservation and future reference the engineering experience of their early days. In the course of events but a few years can elapse ere all the engineering pioneers of our country will have departed.

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TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

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DISCUSSION

ON INCLINED PLANES FOR RAILROADS.

By O. CHANUTE and WILLIAM H. PAINE.

Mr. O. CHANUTE: The valuable paper contributed by Mr. Wells, and the very interesting reminiscences of early American achievements in railroad operating which it has called forth from the members of the Society seem to me to fully confirm the conclusion already reached by railway managers the world over, that the frictional adhesion of locomotive driving wheels upon the rail is sufficient to work almost any gradient likely to be found necessary in practice, and is upon the whole much the most economical to adopt.

Other methods of traction, such as pneumatic tubes, ropes, griping wheels upon a central rail, and racks and cog wheels have gradually been given up, as ineffectual and uneconomical complications; except perhaps for gradients of 15 or 20 feet per hundred, as at Mount Washington and at the Righi, where the latter method is in use. We find that at Madison,* upon a grade of 6 feet per hundred, frictional traction has superseded the rack and cog wheel, and I believe that in all cases where the topography of the country compels the use of gradients of say 4 or 5 feet per hundred, the weight of the boiler and working parts, necessary to generate and apply the power required, will be found sufficient to give the necessary adhesion to utilize that power.

* See Transactions, Vol. VII, page 63.—(March, 1878.)

This, in a measure, results from the improvements which modern practice has introduced in locomotives. These consist mainly in a better distribution of the weights upon the driving wheels, and in America, especially, in equalizing them by levers connecting the drivers with each other, so as to keep the relative weights upon them constant, while allowing them to adjust themselves to the inequalities of the track.

These equalizing levers, together with the centre-bearing truck under the front end of the engine, constitute the leading features of the American locomotive, which is undoubtedly more effective for a given weight than the type still adhered to by the Europeans.

In the early days of railroads it was assumed that an adhesion of $\frac{1}{8}$ or $\frac{1}{9}$ of the weight upon the driving wheels was a satisfactory performance. In France and in England, at the present day, the ordinary practice is to estimate for an adhesion of $\frac{1}{6}$ or $\frac{1}{7}$, while our locomotives work up regularly to $\frac{1}{5}$ in summer and $\frac{1}{4.5}$ in winter, of the weight on the drivers, with occasional performances much in excess.

The account given of the trial trip at Madison is a good case in point.

Upon the 9th of April, 1875, the engine took 210 tons (including its own weight), up a grade of $\frac{1}{16.5}$ or 6.06 feet per hundred, on a straight line, at a speed of 6 miles per hour. The resistance may, therefore, be estimated as follows :

Gravity,	$\frac{6.06 \times 2000}{100}$	= 121.20	pounds	per	ton.
Wheel friction generally	=	6.	"	"	"
Atmospheric resistance, say	=	1.80	"	"	"
Total resistance,		129.	"	"	"

Traction = 210 tons × 129 pounds = 27090 pounds.

As the engine weighed 112 000 pounds or 56 net tons.

Adhesion, $= \frac{27090}{112000} = \frac{1}{4.13}$ or nearly one quarter.

Recent performances on the Boston and Albany Railroad gave an adhesion, if I remember rightly, of $\frac{1}{3.6}$, while on the 3d of July, 1877, the "*Mogul*" locomotive "*Oakland*," started from a stand still "on a grade "of 83 feet per mile, combined with a 2-degree curve, 45 empty eight-"wheeled cars, weighing 669,500 pounds, or 334.75 net tons, and with-"out slipping her drivers took the train up and beyond the gradient, "something more than half a mile, gaining speed and steam as she

"went," as reported by Mr. J. M. Goodwin, Engineer of the Sharpsville and Oakland Railroad, in a letter recently printed by the builders of the locomotive.

As the gradient is one of 1.58 feet per 100, the resistance is estimated as follows :

$$\text{Gravity } \frac{1.58 \times 2000}{100} = 31.60 \text{ pounds per ton.}$$

2 degree curve at ½ pound per °,	1.00	"	"	"
Wheel friction,	6.00	"	"	"
Atmospheric resistance, say,	1.40	"	"	"
Total resistance,	40.00	"	"	"

Traction—Train.. 334.75 tons.
Engine, 33.50 "
Tender, 15.00 "

Total, 383.25 tons × 40 pounds = 15,320 pounds.

$$\frac{\text{Adhesion.....15,320 lbs.}}{\text{Weight on drivers..57,000 lbs.}} = \frac{1}{3.72} \text{ ratio of adhesion.}$$

A performance by no means to be regarded as singular, as the new "consolidation" engines upon the Erie Railway work regularly up to a maximum traction of 19,500 pounds, as measured by the dynamometer and have occasionally indicated 22,000 and 24,000 pounds, with a weight upon their eight driving wheels of 87,500 pounds.

$$\text{In this case the adhesion is } \frac{19,500}{87,500} = \frac{1}{4.49}$$

The usual method of computing train resistances being to allow 10 or 10½ pounds per ton, while I have above stated the wheel friction at only 6 pounds per ton, it may be well to explain how it is arrived at.

In 1854 the late Mr. Zerah Colburn made a number of careful experiments on the Erie Railway, from which he deduced the conclusions that the resistance from wheel friction upon a straight line was 4½ pounds per ton, and on curves ½ pound per degree in addition.

The train which he experimented with, however, was specially prepared for the occasion, and more perfect in lubrication and fitting of journal bearings than those met with in ordinary practice. We find, by recent experiments with a dynamometer upon the Erie Railway, that the wheel friction of ordinary trains on a straight line is generally 5¼ pounds per ton, but we call it 6 pounds to be safe. We find also that

the additional curve resistance is as near as may be ½ pound per ton per degree, as stated by Mr. Colburn.

The atmospheric resistance varies, of course, with the square of the speed, or nearly so, as it is mainly composed of the end pressure, varying as the square of the speed, and the friction of the air upon the sides of the train, which, in consequence of the gaps between the ends of the cars it is difficult to estimate accurately. We found that with two empty freight cars, at 30 miles an hour, the atmospheric resistance was 700 pounds, and with 20 empty cars at the same speed it was 900 pounds. In the first instance it was, therefore, 35 pounds per ton, and 4½ pounds per ton in the second. But if the cars had been loaded it would have been no more in the aggregate, and expressed in terms of the tonnage, would have been 17½ and 2¼ pounds per ton respectively.

As the end surface of a freight car is about 100 square feet, and the air pressure due to a speed of 30 miles an hour is 4.43 pounds per square foot, it will thus be seen that the atmospheric end resistance was 443 pounds, while the remaining 257 pounds in the first case, and 457 pounds in the latter case were due to the friction against the sides and the pressure against the partly uncovered ends of the cars succeeding that on the front end of the trains. For ordinary loaded trains, consisting of 25 to 40 loaded cars, we usually allow from 2 pounds to 1.20 pounds per ton for atmospheric resistance, at speeds varying from 15 to 25 miles per hour.

To the question asked by one of the members present, as to what gradient is required to work a railroad by gravity, I would answer, that if the wheel friction is correctly stated at 6 pounds per ton, the equivalent angle of repose would be 0.30 per 100 feet, or 16 feet per mile on a straight line. The curves adding a resistance of a half pound per degree, would, if ruling at 4 degrees, or 1 432 feet radius, add 2 pounds per ton to that on a straight line, or 0.10 per 100 feet, thus making the angle of repose $\frac{(6+2)\,100}{2\,000} = 0.40 = 21.12$ feet per mile, while, when we take into account the atmospheric resistance at 25 or 30 miles per hour, and the expediency of having a surplus power (to be controlled by brakes), in order to start the cars promptly, and to get the trains out of the way of those following them, we find that in practice we need gradients of about 40 feet per mile to work trains by gravity, which corresponds to a resistance of 15.2 pounds per ton, or 0.76 per 100 feet.

Mr. William H. Paine,—I have visited a number of inclined planes within the past few years, for the purpose of investigating the subject of wire rope traction.

The most extensive and best appointed of those which I have seen operated in this manner are located on the Central Railroad of New Jersey, at Solomon's Gap, near Wilkesbarre, Pa.

There, by three inclines, a height of more than 1 000 feet is attained in less than 3 miles thereby avoiding a detour on the main line of 13 miles. This short cut is devoted to coal traffic.

The principal characteristics of these planes are as follows :

PLANE.	LENGTH.	RISE.	RISE.	FALL.	LOAD.
	Feet.	Per cent.	Feet.	Feet.	Tons.
No. 1	3 700	9.28	334.7		144
Level	600			5.40	
No. 2	3 000	14.65	422.2		99
Level	720			6.75	
No. 3	5 000	5:70	269.		198
Total	13 020		1 025.9	12.15	

Incline No. 1 was operated with an iron wire rope 2¼" diameter. One rope had hauled 7 000 000 tons before it was laid aside. The average speed was 6 miles per hour..

The method here employed, as on most other such planes, was the alternating system. After the train was hauled up, the cars were run back by reversing the engine. A dummy, or pusher, was permanently attached to the rope, which pushed the cars before it in ascending.

The advantages of a circulating system over this method seemed very apparent, as then the rope would run continuously in one direction, the loaded cars ascending on one track and the empty cars descending on another.

The one thing required to make such a plan practicable was a suitable attachment by which the cars could be secured to the rope in such a manner as to allow them to start slowly and gradually acquire the full speed of the rope.

This I have been able to accomplish by the following device. (See

FIG. 1.

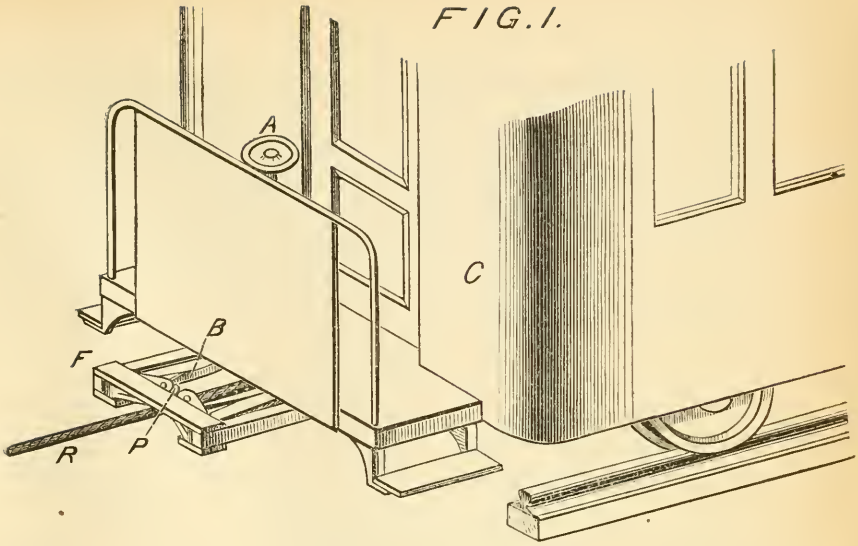


FIG. 2.

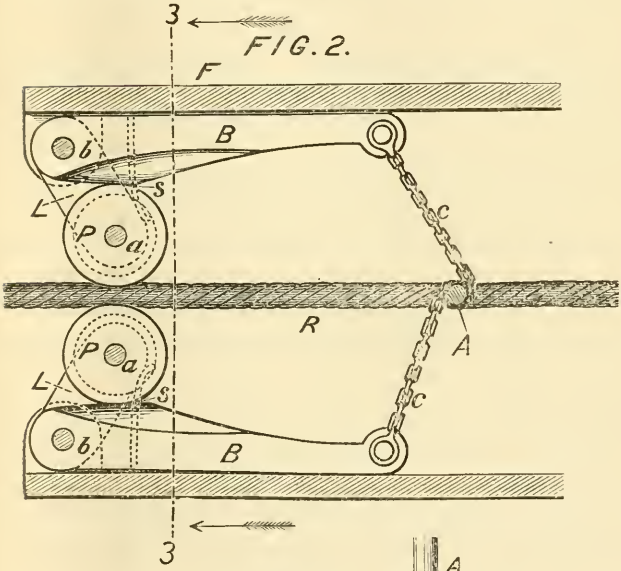


FIG. 3.

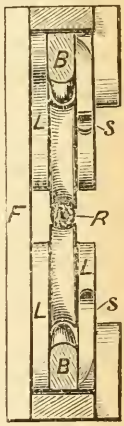
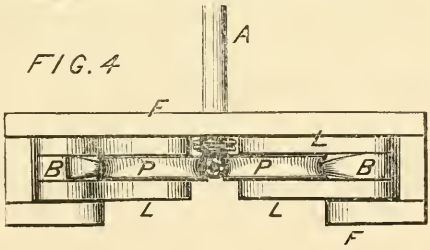


FIG. 4



cut.) In a frame attached under the front end of a car are one or more pairs of grooved rollers, so placed as to embrace the moving rope between their grooved faces. Brakes are applied to these rollers so as to press them against the rope more tightly and at the same time retard their motion. This causes the car to start, and its speed to be accelerated in proportion to the amount that the rollers are retarded in their revolutions. When the revolutions of the rollers are wholly stopped the car will have acquired the full speed of the rope.

REFERENCES.

R.—The moving rope.

PP.—The grooved rollers.

LL.—Links carrying the rollers and pivoted on the frame at their other ends.

BB.—Brakes operating against the rollers.

A.—Rod or capstan on which the chains are wound which move the brakes.

When the car is stationary, and the brakes free, the rollers will be revolved by the moving rope ; but by applying the brakes, so as to retard the motion of the rollers, the car will move forward at any desired speed up to that of the rope.

This system has been adopted on the Sutter Street Railroad in San Francisco, where it has been in successful operation for more than a year.

The Superintendent writes that nothing better could be devised. It will take a heavy load up the steepest grades on the road, and run at any speed desired equal to or less than the speed of the cable without wearing the rope or cutting the rollers.

I have collated the characteristics of this road, and also of the Clay Street Road, which latter is run by brakes, engaging the rope directly without intervening sheaves.

A peculiarity of both of these roads is the fact of running the rope under ground in a large tube having a narrow slit along the top, through which passes the stem which carries the attachments.

Sutter street inclines are 5,315 feet long ; steepest grade, 7.27 feet per hundred.

Clay street, length 3,389 feet ; steepest grade, 16 feet per hundred.

I find a description with plates of both these roads in *Annales des*

Ponts et Chausses for November last. Photographs are also at the rooms of the American Society of Civil Engineers.

This method of attaching cars to moving ropes seems capable of a wider application than simply upon inclined planes, as there are many other places where it would be desirable to dispense with the locomotive, if possible, as on elevated railroads, on bridges, and in tunnels.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

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TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CLXVII.

(Vol. VII.—August, 1878.)

DISTRIBUTION OF RAIN-FALL DURING THE GREAT STORM OF OCTOBER 3 AND 4, 1869.

By JAMES B. FRANCIS, C. E., Member of the Society.

Read at the Tenth Annual Convention, June 18th, 1878.

In the construction of catch-water reservoirs, mill dams, culverts in railway and other embankments, and many other works, provision has to be made for the maximum flow of water. In small areas this depends, to a great extent, on the maximum rain-fall in a given time.

The proportion of the rain-fall that flows off during a given time varies very much, depending on the extent and character of the water-shed and other circumstances. In each case the various considerations

affecting it have to be taken into account in deciding on the flow that should be provided for.

In small areas the fundamental datum is, however, the amount of rain-fall to which the locality is liable in a given time, leaving the proportion of the same that ought to be provided for, to be determined by experience or the judgment of the engineer.

As a contribution to the knowledge on this subject, I submit to the Society some facts and deductions from the same, relating to a great rain that occurred in the eastern part of the United States in October, 1869.

The newspapers of the time contained accounts of the great floods that resulted from this rain in various parts of the country, and put it beyond question that in some localities it was very extraordinary. Being at the time much interested in the subject, I addressed a circular to the meteorological observers for the Smithsonian Institution, in the Eastern States, and other persons and institutions likely to have observed the amount of rain-fall.

The following table has been compiled principally from the replies to this circular.

To ascertain approximately the areas on which certain amounts of rain fell, I have prepared a map of a large part of the region in which the rain-fall at certain points was ascertained.

This map has been compiled, mainly, from maps recently issued by the United States Post Office Department. Several of these maps are on a scale of six miles to the inch. These have been put together, and the map has been completed by reducing those on a different scale to the same scale of six miles to the inch.

In this manner I have obtained a map on an unusually large scale, embracing nearly the whole of the New England States and parts of New York, New Jersey and Pennsylvania, and from the data contained in the following table, I have projected on it isohyetal lines, or lines of equal rain-fall, representing the rain-fall during this storm. A reduced copy of part of this map accompanies this paper.

TABLE I.

Amount of Rain collected in Rain Gauges at the several stations named, during the great storm which ended in Massachusetts on Monday, October 4, 1869.

STATIONS, &c.	Observer or informant.	TIME. Commenced Raining.	TIME. Stopped Raining.	Depth of Rain in inches.	REMARKS.
DOMINION OF CANADA.					
Quebec	Rev. Father Anthony	Oct. 3	Oct. 5	0.91	
Montreal	Louis Lesage	" 2	" 4	2.05	
Halifax	G. Murdock			1.58	
St. John	Do.	Oct. 4, 6 P. M	Oct. 5, A. M.	0.53	
MAINE.					
Houlton	C. H. Fernald	Oct 3, 10 A. M.	Oct. 5, 5 P. M.	3.61	
Steuben	J. D. Parker	" 4, 9 "	" 4, 8 "	0.60	
Williamsburg	E. Pitman		" 4,	5.30	
Orono	M. C. Fernald	Oct. 3, 2:30 P. M.	" 5, 1:30 P. M.	2.13	
West Waterville	B. F. Wilbur	" 3, 6 A. M.	" 4, 6:40 "	4.10	
Gardiner	R. H. Gardiner			3.37	
Lisbon	A. P. Moore			2.70	
Rumford	W. Pettingill			8.00	
Norway	H. D. Smith	Oct. 3, 6 A. M.		6.70	2.50 inches of rain fell in two hours, Oct. 4, P. M.
Standish	J. P. Moulton			4.31	
Fort Preble, Portland	Dr. E. Cowles	Oct. 3, 5:30 A. M.	Oct. 4, 6 P. M.	1.99	
Cornish	Siles West	" 3, 4 "	" 4, 5 "	6.43	
Do.	G. W. Guptill	" 3	" 4	6.15	

New Hampshire.					
Dover	Asa A. Tufts			3.20	
North Barnstead	Charles H. Pitman		Oct. 4	7.40	
Weir's Landing	Josiah B. French			6.40	
Lake Village	Do.			6.77	
Goffstown	Alfred Colby		Oct. 4, P. M.	8.06	4.27 inches of rain fell between 11 A. M. and 2 P. M. Oct. 4.
Concord	W. L. Forster	Oct. 2, 12 P. M.	" 4, "	7.40	4.00 inches of rain fell between 0:30 P. M., and 2:30 P. M., Oct. 4.
Hanover	Shattuck Observatory	" 3, A. M.	" 4, 5 P. M.	5.88	
Vermont.					
Lunenburgh	H. A. Cutting			4.00	
North Craftsbury	Rev. E. P. Wild	Oct. 3	Oct. 5	4.49	
Randolph	C. S. Paine		" 4	5.28	
Burlington	University of Vermont	Oct. 3	" 5, A. M.	3.71	
West Charlotte	Miss M. E. Wing		" 5, 9.15 A. M.	5.00	
Panton	D. C. Barto			4.25	
Middlebury	H. A. Sheldon	Oct. 3, 6 A. M.	Oct. 5, 11 A. M.	3.98	
Castleton	Rev. R. G. Williams	" 3, 4 "	" 5, 1 P. M.	6.57	
Woodstock	H. Doton	" 3, 6 "	" 4, 5 "	6.35	
Massachusetts.					
Kingston	G. S. Newcomb		Oct. 4	1.75	
New Bedford	Samuel Rodman	Oct. 3, 8 P. M.	" 4, 4:30 P. M.	1.50	
Milton	Rev. A. K. Teele			1.15	
West Roxbury	Thomas Motley			1.46	
Jamaica Plain	J. J. Dixwell	Oct. 3	Oct. 4	1.45	
Fort Warren	Dr. J. H. Kinsman			0.90	
Boston	W. H. Bradley	Oct. 3	Oct. 4	1.76	
Do.	Robt. Treat Paine	" 3	" 4	1.52	
Topsfield	S. A. Merriam		" 4	1.77	
Georgetown	S. A. Nelson	Oct. 3, 0:10 P. M.	" 4, 6 P. M.	2.25	
Lawrence	John Fallon	" 3, 12 M.	" 4, 4:30 P. M.	3.56	
Cambridge	Harvard College Obser.	" 3	" 4	1.58	
Waltham	S. R. Scott			1.65	

TABLE I.—*Continued.*

STATIONS, &c.	Observer or Informant.	TIME. Commenced Raining.	TIME. Stopped Raining.	Depth of Rain in inches.	REMARKS.
West Newton	J. H. Bixby			2.23	
Lake Cochituate	A. Stanwood			4 00	
Lowell	Merrimac M'f'g Co.			3.12	
Do.	Prop's locks and canals			2.84	
Lunenburg	G. A. Cunningham	Oct. 3	Oct. 4.	7.60	
Fitchburg	Dr Jabez Fisher	" 3	" 4	7.53	About 3 inches of rain fell between 11:30 A. M. and 2 P. M., Oct. 4.
Worcester	Dr. Joseph Draper		" 4	4.75+	Rain gauge overflowed.
Amherst College	Prof. E. S. Snell	Oct. 3	" 4	5.83+	Do. do.
Chicopee	C. H. Nye			8.71	
Springfield	L. C. Allen, U. S. Army	Oct. 3, 2 A. M.	Oct. 4, 3:15 P. M.	8.05	
Do.	J. Weatherhead		" 4	7.50	
Hinsdale	Rev. E. Dewhurst	Oct. 3		6.80	
Pittsfield	Thos. Colt		Oct. 4	6.00	
Williams College	Prof. A. Hopkins			6.00	
Richmond	Wm. Bacon	Oct. 3, 3 P. M.	Oct. 4, 3 P. M.	3.97	More than one half the quantity fell between 8 A. M. and 11 A. M. Oct. 4.
RHODE ISLAND.					
Fort Adams		Oct. 3, 8:40 P. M.	Oct. 4, 10:30 A. M.	0.90	
Providence	Dr. Caswell			0.83	
CONNECTICUT.					
Hartford	Prof. Pynchon			8.43	At Water Works Reservoir.
Do.	C. J. Hoadly		Oct. 4, 3 P. M.	8.11	Rain gauge supposed to have overflowed.

Canton	Geo. I. Case			12.35	
New Haven	Prof. Loomis			4.30+	Rain gauge overflowed.
Do.	Dr. Munson			6.00+	Do. do.
Middletown	Prof. Johnston	Oct. 3	Oct. 4	8.90	The whole amount fell in a little more than 30 hours.
Do.	H. D. A. Ward	" 3	" 4	9.37	7.15 inches of rain fell between 2 P.M. Oct. 3, and 2 P.M. Oct. 4, the whole quantity in 37 hours.
Colebrook	Miss C. Rockwell	Oct. 3, 3 A. M.	Oct. 4, 9 P. M.	8.44	
Brookfield	Rev. S. W. Roe			5.50	
NEW YORK.					
Moriches	E. A. Smith	Oct. 3. 8:50 A. M.	Oct. 4, 1:30 P. M.	5.34	
Fort at Willet's Point	Gen. H. L. Abbot	" 3, 12 P. M.	" 4, 1 P. M.	7.85	
Flatbush	Rev. E. T. Mack	" 2, 9:30 P. M.	" 4, P. M.	3.46	
Fort Schuyler	Gen. H. L. Abbot			8.00	
City Hall Park	Croton Aq. Dept	" 3, 11 P. M.	Oct. 4, 12 M.	4.11	
Central Park	Central Park Com			3.92	
New Reservoir, 86th st.	Croton Aq. Dept		Oct. 4	4.09	
High Bridge	" "		" 4	4.50	
Tarrytown	" "		" 4	4.45	
Croton Dam	" "		" 4	5.10	
Kent	" "		" 4	5.23	
Ardenia	T. B Arden			4.63	
West Point	J. Muller, Hos. Stw'd		Oct. 4, 11.30 A. M.	5.25	
Newburgh	Jas. H. Gardiner			5.30	
Middlehope	Leander Clark			4.77	
Glasco	D. B. Hendricks			4.75	
Hudson	Dr. G. P. Hackenberg			7.90	
Albany	Prof. Ten Eyck	Oct. 3	Oct. 5	6.01	
"	Dudley Observatory	" 3, 5:30 P. M.	" 4, 12 M.	5.86	
Troy	Water Commissioners.	" 3	" 5	5 46	
South Hartford	G. M. Ingalsbe	" 3, 1 P. M.	" 5, 3 P. M.	5.89	
Plattsburgh Barracks	Maj.-Gen. Arnold	" 3, 1 A. M.	" 5, 8 P. M.	3.01	
Minaville	J. W. Bussing	" 3	" 4, 9:30 A. M.	5.25	

TABLE I.—*Continued.*

STATIONS, &c.	OBSERVER OR INFORMANT.	TIME. Commenced Raining	TIME. Stopped Raining.	DEPTH OF RAIN IN INCHES.	REMARKS.
South Trenton	Storrs Barrows	Oct. 1	Oct. 4	2.28	
Leyden	C. C. Merriam	" 2	" 4, P. M.	3.60	
Houseville	Walter D. Yale	" 3	" 5, 8 A. M.	2.02	
Gouverneur	C. H. Russell	" 2	" 5, A. M.	2.87	
North Hammond	C. A. Wooster	" 2, 6:20 P. M.	" 5, A. M.	3.35	
Oneida	Dr. S. Spooner	" 3	" 4	5.84	
Palermo	E. B. Bartlett		" 5, A. M.	2.70	
Oswego	W. S. Malcolm			2.15	
Depauville	Henry Hass	Oct. 4, 6 A. M.	Oct. 4, 3 P. M.	2.60	
Newark Valley	Rev. S. Johnson	" 2, 5 P. M.	" 5	2.80	
NEW JERSEY.					
Paterson	Wm. Brooks	Oct. 3	Oct. 4	4.15	
Newark	W. A. Whitehead	" 3, 0 A. M.	" 4, 12 M.	3.33	
Newton	Dr. T. Ryerson	" 3, 3 A. M.	" 5, 8:30 A. M.	7.11	5.21 inches of rain fell between Oct. 3, 4:30 P. M., and Oct. 4, 9 A. M.
New Germantown	Arthur B. Noll	" 3, 5 A. M.	" 3, 8.30 P. M.	4.43	
Trenton	E. R. Cook		" 4	2.61	
Haddonfield	John Beadle		" 4	3.32	
Vineland	Dr. J. Ingram	Oct. 3, 5 A. M.	" 4, 10 A. M.	2.87	
Greenwich	Rebecca C. Sheppard	" 3	" 4	3.25	
Rio Grande	Mrs. J. R. Palmer		" 4	3.50	
Moorestown	Thos. J. Beans	Oct. 3, 9 A. M.	" 4, 8 A. M.	2.41	
PENNSYLVANIA.					
Nyces	John Grathwohl	Oct. 3, 4 A. M.	Oct. 4, 8 A. M.	7.50	
Hamlinton	J. D. Stocker	" 1	" 3, 6 A. M.	6.00	

Dyberry	Theodore Day	" 3	" 4, 9 "	4.15	3 inches of rain fell during the night of Oct. 3.
Fallsington	E. Hance	" 3, 8 A. M.	" 4, 11 "	2.90	
Horsham	Miss Anna Spencer		" 4	4.00+	Rain Guage overflowed.
Plymouth Meeting	M. H. Corson	Oct. 3, 6 A. M.	" 4, 10:30 A. M.	6.00	
Penn. Hospital	Dr. Conrad	" 3	" 4, 10:30 "	3.85	
Cor. 7th & Thompson Sts.	Jacob M. Ellis	" 2 P. M	" 4, 9 A. M	4.25	
Western part of Phila	Do.			3.75	
Germantown	Do.			5.20	
Westchester	Dr. Geo. Martin			3.76	Rain Gange filled to within ¾ inch of top; probably a portion lost by splashing over.
Do.	Dr. Jesse C. Green			5.80	
Parkerville	Dr. F. Darlington	Oct. 3, A. M.	Oct. 4, 10 A. M.	5.24	
Phœnixville	Dr. J. L. Coffman			7.10	
Reading	J. Heyl. Raser	Oct. 3, 3:15 A. M.	Oct. 4, A. M.	6.73	
Ephrata	W. H. Spera	" 2, 11:35 "	" 4, 4 A. M.	8.05	
Mount Joy	Dr. J. R. Hoffer			....	Rain Gange out of order. Rainfall stated to be between 8 and 9 inches.
Factoryville	Rodman Sisson	Oct. 3, 1 A. M.	Oct. 4	4.67	
Tioga	E. T. Bently	" 2, 10 P. M.		2.00	
Lewisburg	Prof. C. S. James			3.60	
Carlisle	Dr. W. H. Cook	Oct. 2, 1 P. M.	Oct. 4, 2 A. M	4.50	
Fountain Dale	S. C. Walker	" 2, 2:30 P. M.	" 4, 3 "	4.58	
Grampian Hills	Elisha Fenton	" 2, 10 P. M.		0.57	
Johnstown	David Peelor	" 2, 7 P. M	Oct. 3, 9 "	0.76	
Franklin	Rev. M. A. Talman	" 2, 3:30 P. M.	" 5, 3:30 P. M.	0.47	
Canonsburg	W. Smith	" 2	" 4	1.40	
DELAWARE.					
Milford	Mrs. A. C. Whittier			1.50	
MARYLAND.					
Woodlawn	J. O. McCormick	Oct. 2	Oct. 4, 5 A. M.	3.97	

TABLE I.—*Continued.*

STATIONS, &c.	OBSERVER OR INFORMANT.	TIME.		DEPTH OF RAIN IN INCHES.	REMARKS.
		Commenced Raining.	Stopped Raining.		
MARYLAND—(*Continued.*)					
Annapolis	W. R. Goodman	Oct. 2, 11:30 P. M.	Oct. 4, 6:20 A. M.	5.25	
Mt. St. Mary's	Prof. C. H. Jourdan	.....	" 4	5.12	
DIST. OF COLUMBIA.					
Washington	Smithsonian Institution	Oct. 3, A. M.	Oct. 4, A. M.	6.55	
VIRGINIA.					
Johnsontown	C. R. Moore	Oct. 3, 6:30 P. M.	Oct. 4, A. M.	1.05	
Comorn	E. Tayloe	" 3, daybreak.	" 4, 7 P. M.	5.42	5.05 inches of rain fell October 3d, between daybreak and midnight.
Fortress Monroe	Artillery School, U. S. A.	Oct. 2	" 3	1.98	
Hampton	J. M. Sherman	" 2, 4 A. M	" 4, 5 A. M	3.30	
Zuni Station	R. Binford	" 2, 11 "	" 3, 2 A. M	3.16	
Bacon's Castle	B. W. Jones	" 3, 8 "	" 4, A. M.	3.80	
Staunton	J. C. Covell	.....	" 4	2.25	
Lexington	W. H Ruffner	Oct. 2, A. M.	" 3, 4:30 P. M.	2.75	
Snowville	J. W. Stalnaker	" 2, 7 P. M.	.....	1.20	

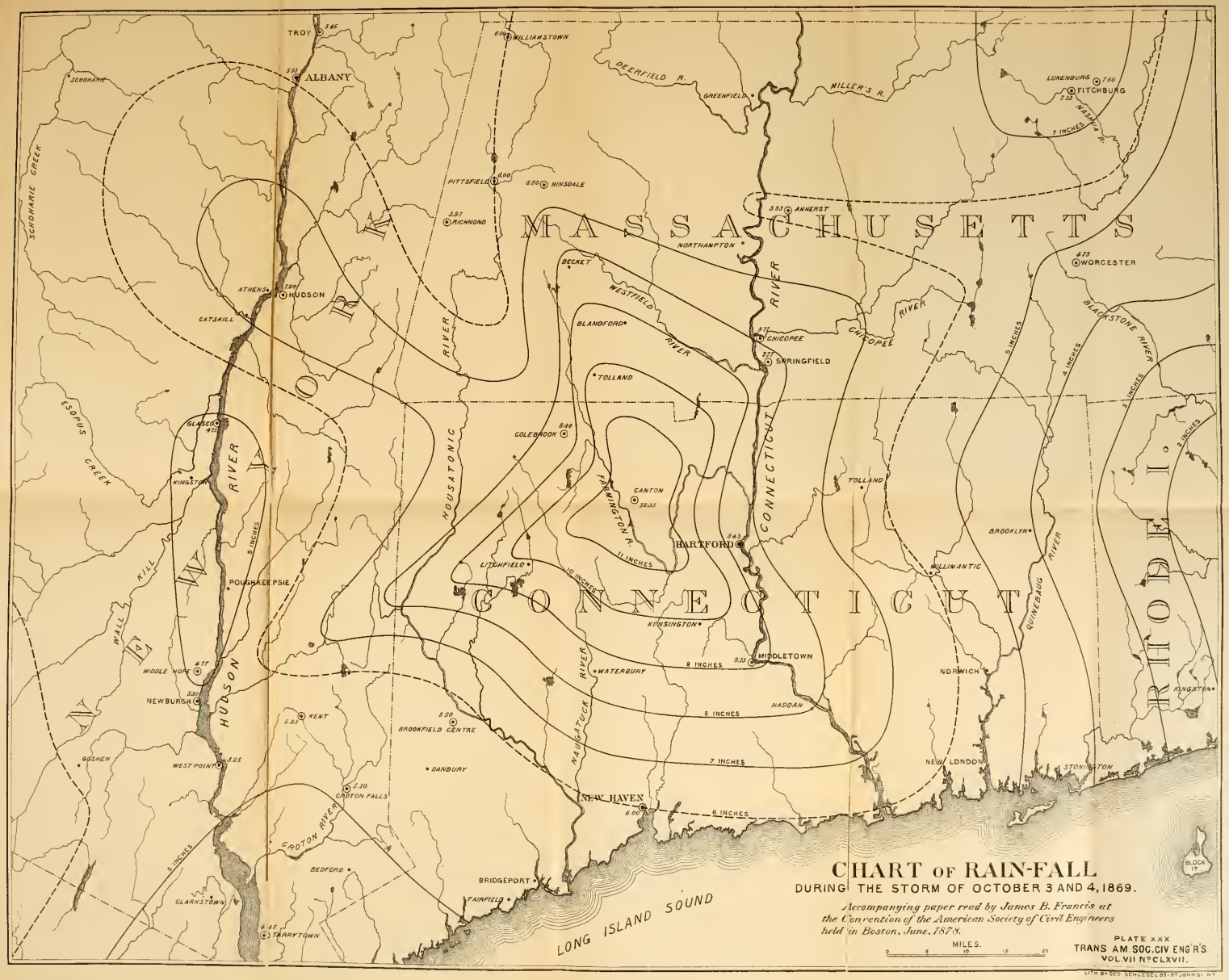
CHART OF RAIN-FALL
DURING THE STORM OF OCTOBER 3 AND 4, 1869.
Accompanying paper read by James B. Francis at the Convention of the American Society of Civil Engineers held in Boston, June, 1878.
PLATE XXX
TRANS. AM. SOC. CIV. ENG'RS.
VOL. VII No. CLXVII.
MASSACHUSETTS
CONNECTICUT
NEW YORK
RHODE ISLAND
LONG ISLAND SOUND
HUDSON RIVER
CONNECTICUT RIVER
HOUSATONIC RIVER
NAUGATUCK RIVER
FARMINGTON R.
WESTFIELD RIVER
CHICOPEE RIVER
BLACKSTONE RIVER
QUINEBAUG RIVER
CROTON RIVER
WALL KILL
ESOPUS CREEK
SCHOHARIE CREEK
DEERFIELD R.
MILLER'S R.
NASHUA R.
TROY
ALBANY
WILLIAMSTOWN
GREENFIELD
LUNENBURG
FITCHBURG
PITTSFIELD
HINSDALE
RICHMOND
AMHERST
NORTHAMPTON
WORCESTER
BECKET
ATHENS
HUDSON
CATSKILL
BLANDFORD
CHICOPEE
SPRINGFIELD
TOLLAND
GLASCO
KINGSTON
GOLEBROOK
CANTON
HARTFORD
LITCHFIELD
POUGHKEEPSIE
BROOKLYN
WILLIMANTIC
KENSINGTON
MIDDLETOWN
WATERBURY
NORWICH
MIDDLE HOPE
NEWBURGH
KENT
BROOKFIELD CENTRE
HADDAM
GOSHEN
WEST POINT
DANBURY
NEW LONDON
STONINGTON
CROTON FALLS
NEW HAVEN
BEDFORD
BRIDGEPORT
FAIRFIELD
CLARKSTOWN
TARRYTOWN
BLOCK 19
MILES.
0 5 10 15 20
LITH. BY GEO. SCHLEGEL, 85 ST. JOHN'S, N.Y.

It is obvious that the observations collected in Table I are quite insufficient for an accurate determination of the isohyetal lines, and until meteorological observers are greatly multiplied, a rough approximation is all that can be attained in such an investigation.

In projecting the lines it is assumed that the amount of rain varies uniformly from one station to the next. In some cases the stations are very far apart. Fortunately for our purpose, however, where the rainfall was the greatest, the stations were not so distant from each other, and the results may consequently be taken as nearer approximations.

According to the observations, the fall of rain was greatest at Canton, in Connecticut, about fifteen miles northwesterly of Hartford, where the gauge indicated 12.35 inches.

Mr. George I. Case, the observer, said in reply to the circular: "I measured 12.35 inches, but I do not think it could possibly have been so much. I think there was an unaccountable mistake somewhere." He appears to have had no reason to question the accuracy of his measurement except the extraordinary amount, but as the observations at other points in the vicinity, although indicating much less rain, are consistent with it as a culminating point, I see no reason for discrediting his observation.

As will be seen by the preceding table of observations, the storm extended southerly to New Jersey, Pennsylvania, Maryland, Washington and Virginia. I have, however, not attempted to map its course systematically, except in the New England States, and a small part of the State of New York, in Dutchess, Columbia, and Albany Counties, and parts of adjoining counties.

Omitting the part of the State of New York and other States not systematically mapped, it appears from the isohyetal lines that the watershed on which six inches or more of rain fell, is embraced in a single closed curve, extending from Long Island Sound to the northeasterly part of Maine, a distance of about 384 miles, with an average width of about 63 miles.

The area on which seven inches or more of rain fell is embraced within two closed curves with an interval between them, near the middle of Massachusetts, of about 30 miles.

The area on which eight inches or more fell extends from Haddam, in Connecticut, to Becket, in Massachusetts, a distance of about 65 miles, with an average breadth of about 28 miles.

The area on which nine inches or more fell extends from Middletown, in Connecticut, to the neighborhood of Blandford, in Hampden County, Massachusetts, a distance of about 50 miles, with an average width of about 21 miles.

The area on which ten inches or more fell extends from Kensington, in Connecticut, to near Tolland, Massachusetts, a distance of about 34 miles, with an average width of about 15 miles.

The area on which eleven inches or more fell is entirely within the State of Connecticut, with Canton for its central point; the extreme length is about 20 miles, and average width about 9 miles.

Table II gives the areas of water-shed on which rain of not less than certain depths fell during October 3d and 4th, 1869, obtained by planimeter and checked by scale from the map described above, all being embraced within single closed curves, except for seven inches, as described above. It will be understood that the area given for any rain-fall includes the entire area within its bounding curve, and, according to the method adopted, the rain-fall on every part of the area equals or exceeds the amount stated.

For example, the area for a rain-fall of nine inches, or more, given in the table, is 1,046 square miles. This area includes the 519 square miles given for ten inches, or more, and that again includes the 179 square miles on which the rain-fall was eleven inches, or more.

Strictly speaking, it is assumed that the rain-fall at the isohyetal line forming the bounding curve is just the amount stated, and that it increases uniformly to the next included isohyetal line, where it is one inch greater.

TABLE II.

DEPTH OF RAIN.	AREA OF WATER-SHED.
6 inches or more	24,431 square miles.
7 " "	9,602 " "
8 " "	1,824 " "
9 " "	1,046 " "
10 " "	519 " "
11 " "	179 " "

In Table I the fall of rain during certain parts of the storm is given by some of the observers, indicating a great inequality at different times.

At Concord, New Hampshire, out of the whole rain-fall of 7.40 inches, four inches fell in two hours on the afternoon of the second day of the storm, and undoubtedly in many other localities there was a like down-pour, and in some places even more.

This inequality in the rate has an important bearing on the effect of such a storm on small areas.

The long continued and heavy rain must have filled up the ground and usual storage reservoirs, and, being followed immediately by a fall of rain which of itself would make a flood, great part of the latter in a hilly country must have passed at once into the streams, and the flow in the smaller streams, for some period of time, must have been nearly that due to the rate at which the rain was falling on the water-shed supplying them. In the larger streams, supplied from correspondingly larger areas, the discharge is spread over a longer time, and the rate of flow would, of course, be proportionally less.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CLXVIII.

(Vol. VII.—August, 1878.)

THE GAUGING OF STREAMS.

By CLEMENS HERSCHEL, C. E., Member of the Society.

Read at the Tenth Annual Convention, June 18th, 1878.

All I shall have to say upon the subject of the gauging of streams will be in the nature of two simple suggestions to the Committee, relative to the form in which the records of the gauging of streams should be finally published.

In the first place, as to the measure to be used. We had a paper* not very long ago in the Transactions of the Society on the "Floods of

* See Vol. IV, page 297, December, 1875.

Rivers," and, what to me seemed somewhat curious, the unit chosen was "cubic feet per minute per acre." Now, I think hydraulic writers of eminence are pretty well agreed on one thing—that the unit of measure for running streams should be cubic feet per *second*, and not per *minute*. And they are tolerably agreed also that the *acre* is a rather small area by which to measure drainage areas, and that the *square mile* is much better. And, in fact, the "cubic foot per minute per acre" sounds, to my ears, very much like an importation from Great Britain, which is responsible for a great many very curious and inconvenient dimensions in engineering literature. For one, I hope that "cubic feet per minute per acre" will be banished, and that "cubic feet per second per square mile" will take its place in all these gaugings, to be supplemented and eventually replaced by the cubic meter per second per square kilometer, or the cubic decimeter, or liter, per second per square kilometer, the latter being one thousand times the former. That is one point.

The next point is how, after the quantities are reduced to cubic feet per second per square mile, to portray the flow of a river so that its principal features may be arrived at in a short time. Any one who has ever tried to testify about a river in court, will have noticed, I venture to say, what an awkward thing it is, to describe in a lucid manner. The tendency is to speak of "the six dry months and the six wet months"—of "the six summer months and the six winter months." These begin sometimes in one month and sometimes in another. Oftentimes, beginning with May, the six months following are called the six dry months, and the rest of the year is called the six wet months. But, as you will see from this diagram (which I propose to hand around, because it cannot be seen from the blackboard), there is one diagram, of the Merrimack river, which was constructed for the whole year, [and it is al nost perfect], merely from testimony in a certain law-suit relating to what were called the six dry months of the year. This refers to cases tried recently against the City of Boston, where the testimony was given only concerning "the six dry months," beginning with May, and yet among those six dry months, so-called, there is the wettest month in the whole year.

I desire to accompany the statement just made with an explanation. The six months' observations that were given in testimony, I have ar-

ranged, as nearly as I could, in the order they belonged in the whole year, being guided in this task mainly by analogy with the Connecticut river records. Some years the two rivers were almost exactly alike in having such and such months occupy the same places in the order of dryness or wetness. The exact final result is that the diagram given *for the whole year*, and of the Merrimack river, is *probably* nearly correct. On the Connecticut river, May, 1873, was the wettest month in the whole series of forty-eight months, and the other three Mays ranked each next to the wettest month in 1871, '72 and '74. These diagrams very well illustrate that there is really no such thing as "the six dry months" and "the six wet months" of a year, taking them in calendar order. There are, in every year, the six driest and the six wettest months, but they come in no regular order. That brings me to what I was going to say – that the proper way to arrange the months of the year for the purposes of hydraulic engineering is to arrange them, not by their names, and not by their division into seasons, but by this very quality that we are investigating, their wetness and dryness. Let us call the driest month number one; the next driest, be its name what it may, number two, and the wettest will be number twelve.* In that way we may get a diagram which will convey a great deal of meaning to the engineer.

The diagrams accompanying this are drawn for different drainage areas, varying in the numbers of square miles in each, in order to see the effect on the discharge of a river, taking it for a number of years, caused by the size of its drainage area. The diagram indicates in one direction "cubic feet per second per square mile," and in the other direction the relative discharge of the different months in each year. Each year occupies twelve of the horizontal divisions, "one" being the driest, "two" the next driest, "three" the next, until "twelve" is the wettest month of the year. The names of the months are given at each plotted point, so that it may be seen how the wetness and dryness is distributed by months for many years.

The diagram representing the results derived from gaugings of the flow of the west branch of the Croton river is drawn from data given in the paper upon that river, by Mr. J. J. R. Croes, Transactions, Vol. III., p. 76, No. 87. The Sudbury river diagram is founded upon data derived from exact gaugings of that river by the City of Boston, during

* The first suggestion of this method came to me from Mr. Jos. P. Davis, City Engineer of Boston.

the past four or five years. I owe their presentation to kindness of Mr. J. P. Davis, City Engineer, and Mr. A. Fteley his Principal Assistant, in charge of the Additional Supply. The Concord river diagram is drawn from data furnished by accurate gaugings for part of the time, and tolerably accurate ones, controlled by the former, for the rest. This river has figured in so many law-suits in Massachusetts, that a great deal of reliable information has been gathered with regard to it. In 1876 it was gauged every half hour, night and day, for 90 days, by a party of three men, under my charge. Mr. J. P. Frizell, Civil Engineer, late of Boston, has also given me some computations of his own with regard to it. The next diagram, that of the Merrimack river, at Lawrence, is the one that has already been alluded to as being based on data for only six months in each of the years given. The figures used were testified to by Mr. H. F. Mills, of the Essex Company, as being reliable within four per cent., and any one gauging may be either too much or too little by that amount ; on the average they must be nearly correct.

The Connecticut river diagram is based upon data given in one of the reports of our member, Gen. Theo. G. Ellis, made to Gen. G. K. Warren, U. S. Engineers, and printed in the report of the Chief of Engineers, U. S. A., for 1875. The drainage area of the Connecticut I have measured on as good a map as I could find of the territory. I think the result is equally reliable with that given concerning the Merrimack river, but both are less reliable than the drainage areas given for the other three rivers.

Of course, it would be somewhat premature to draw conclusions from an inspection of these five diagrams only. The proper time to do this would be after these five rivers, and many more, had been observed for a great number of years, and all these results reduced to diagrams. But certain general conclusions may be stated now, subject to modification, as facts accumulate. Observe, for example, the greater range, each side of a centre line of the curves, drawn in shaded lines, which "*envelope*" the results of the gaugings of the Croton, or of a small water-shed, as compared with the same range as exhibited successively in the diagrams of the other rivers, supplied by larger drainage areas. A decided result is exhibited in the greater discharge per square mile, or *specific* discharge, if that is a proper term, during the driest months of each year of the rivers, with a large water-shed, as compared with those

having only a small one. In fact, there seems to be a regular law about it, the *specific* discharge during the minimum months being proportional to extent of drainage area. It is never below ½ cubic foot per second per square mile in large rivers, while it runs down to less than 0.1 in the smaller rivers shown ; and reckoning for a period of minimum discharge during six working days only, the contrast is still more glaring. These quantities are indicated on the diagrams by a circle under the value for the driest month. Passing to extremes, it will be evident that certain brooks have a minimum discharge, *specific* or otherwise. during a week, equal to 0, while the Merrimack or Connecticut can never fall below ½ cubic foot per second per square mile during the same length of time : a consideration of some importance, frequently, in estimating the value of streams diverted.

One of the uses to which a diagram of the kind presented may be put, is, in estimating the size of the water-wheels it will pay, commercially, to set and attempt to run for any purpose on any given stream. It will not pay, of course, to put in wheels that can be run to their full capacity in the 10th, 11th and 12th wettest month, or in the 11th and 12th only, and which are but partly supplied with water the other 9 or 10 months in the year. In some situations it may pay to attempt to use more of the freshet water than it can in others ; as for instance, when a cotton or woolen mill, which demands a pretty regular supply of power, is combined with other works which may be run with intermissions, such as a mill for grinding dye-stuffs, or a saw-mill, a grist-mill, &c. But with a diagram, such as presented, before him, every engineer can make his calculations for the place under examination and can come to some sort of a rational conclusion about it, while by taking the observations and arranging them by *calendar* months, my experience is, that not so much as a ray of common sense can be made to penetrate the clouds thus formed about the subject. The table below and the diagrams will need no further explanation.

	Croton West Branch, 20½ Sq. M., 3 yrs. observations, 1870-71-72.	Sudbury, at Framingham. 76.3 Sq. M., 3 yrs. observations. 1875-76-77.	Concord, at Lowell, 352 Sq. M., 2 yrs. 7 mos. observations. June, 74-75-76.	Merrimack, at Lawrence. 4136 Sq. M., May to Oct., inclusive. 1871-2-3-4-5-6.	Connecticut, at Hartford, 10 234 Sq. M., 4 yrs. observations, 1871-72-73-74,
	Cubic Feet per Second per Square Mile of Drainage Area.				
Driest 6 working days.	0.04	0.05	0.17	0.53	0.51
Driest month 1	0 29±0.21	0.20±0.10	0.36±0.12	0.68 ±0.08	0.67 ±0.09
2	0.52±0.40	0.32±0.18	0.41±0.13	0.78 ±0.16	0.75 ±0.15
3	0.80±0.60	0.46±0.24	0.45±0.13	0.93 ±0.25	0.86 ±0.20
4	1.10±0.80	0.64±0.30	0.54±0.16	1.11 ±0.36	1.01 ±0.29
5	1.45±1.00	0.83±0.33	0.67±0.19	1.34 ±0.46	1.21 ±0.39
6	1.85±1.20	1.08±0.38	0.85 ±0.25	1.59 ±0.59	1.48 ±0.52
7	2.30±1.40	1.36±0.42	1.10 ±0.35	1.88 ±0.73	1.76 ±0.64
8	2.85±1.50	1.70±0.46	1.35 ±0.40	2.20 ±0.85	2.09 ±0.75
9	3.50±1.65	2.14±0.56	1.70 ±0.50	2.68 ±0.93	2.51 ±0.87
10	4.20±1.80	2.75±0.80	2.10 ±0.60	3.30 ±1.05	3.08 ±0.93
11	5.05±1.95	3.80±1.35	2.65 ±0.75	4.10 ±1.25	4.00 ±1.10
12	6.65±1.35	6.00±1 50	4.30 ±1.10	5.80 ±1.00	5.85 ±1.05
Max. freshet known.		41.60 Mch. 26, 1876	12.64 Mch. 29-30, 1876.	23.4 In 1852.	20.27 May, 1854.

Addenda.

Since the above paper was written, the U. S. Corps of Engineers have published the gaugings of the Connecticut river for 1875, '76, and '77. I have calculated the corresponding discharges in cubic feet per second, and in cubic feet per second per square mile of drainage area; and arranged the months of each year in their order of amount discharged, or, as it has been called, in their order of dryness. If the data for these three years be plotted on the diagram, it will be seen that they fit very well into the limits marked out from the data of the years 1871 to '74, which alone were available when the diagram was made.

Discharge of the Connecticut River at Hartford—10,234 Square Miles of Drainage Area.

Order of dryness.	Month.	Cubic feet per second.	Cubic feet per second per square mile.
	1875.		
1	Jan.....	6 376	0.62
2	Sept.....	6 739	0.66
3	July.....	8 584	0.84
4	Oct.....	10 225	1.00
5	Feb.....	11 170	1.09
6	Aug.....	11 937	1.17
7	June.....	13 737	1.34
8	Nov.....	15 827	1.55
9	Dec.....	16 272	1.59
10	March.....	18 307	1.79
11	May.....	41 606	4.07
12	April.....	56 346	5.51
	1876.		
1	Aug.....	6 225	0.61
2	Oct.....	6 321	0.62
3	Dec.....	6 405	0.63
4	Sept.....	6 630	0.65
5	Nov.....	8 033	0.78
6	July.....	8 220	0.80
7	June.....	15 821	1.55
8	Feb.....	25 407	2.48
9	Jan.....	29 852	2.92
10	March.....	35 045	3.42
11	May.....	58 065	5.67
12	April.....	62 020	6.06

Order of dryness.	Month.	Cubic feet per second.	Cubic feet per second per square mile.
	1877.		
1	Jan.....	6 534	0.64
2	Sept.....	6 979	0.68
3	Feb.....	7 643	0.75
4	June.....	8 066	0.79
5	Aug.....	8 567	0.84
6	July.....	9 511	0.93
7	Oct.....	11 862	1.16
8	May.....	16 941	1.65
9	Dec.....	17 317	1.69
10	Nov.....	29 254	2.86
11	March.....	34 817	3.40
12	April.....	42 533	4.16

Lowest 6 Working Days.

1875..	Jan. 25–30.....	6 238	0.61
1876..	Aug. 28—Sept. 2....	5 660	0.55
1877..	Jan. 1–6.....	5 937	0.58

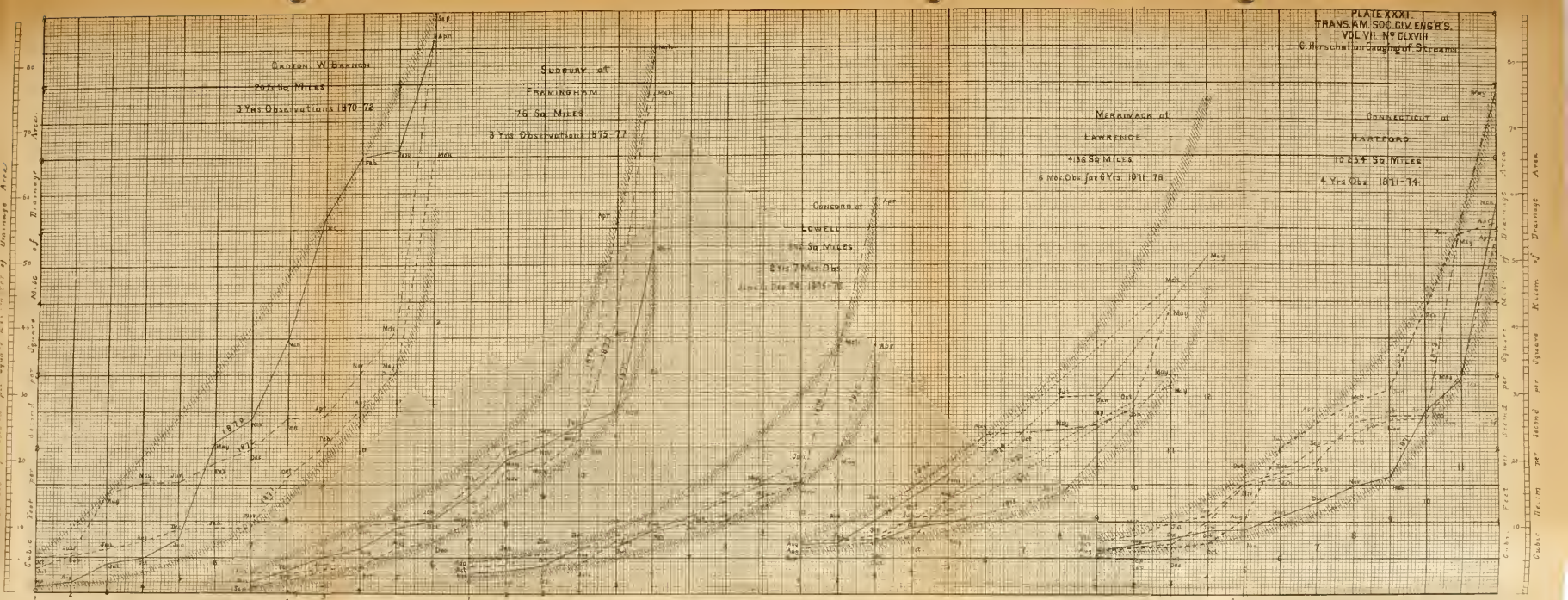
PLATE XXXI.
TRANS. AM. SOC. CIV. ENG'RS.
VOL. VII. No. CLXVIII
C. Hirschel on Gauging of Streams
Croton W. Branch
207.5 Sq. Miles
3 Yrs Observations 1870-72
Sudbury at
Framingham
75 Sq. Miles
3 Yrs Observations 1872-77
Merrimack at
Lawrence
4136 Sq. Miles
6 Mos. Obs. for 6 Yrs. 1871-76
Connecticut at
Hartford
10234 Sq. Miles
4 Yrs Obs. 1871-74
Concord at
Lowell
Cubic Feet per second per square Mile of Drainage Area
Cubic Feet per second per square Kilom. of Drainage Area
1 cu. ft per second per sq mile =
(.0283) cu. decams per sec per sq kilom.
O = Dryest 6 working days.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

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CLXIX.

(Vol. VII.—September, 1878.)

THE DANGERS THREATENING THE NAVIGATION OF THE MISSISSIPPI RIVER

AND THE RECLAMATION OF ITS ALLUVIAL LANDS.

By B. M. HARROD, C. E., Member of the Society.

Read at the Tenth Annual Convention, June 18th, 1878.

When the operations of civilization are first extended into new fields, the pioneer, while acquiring rights and benefits, inevitably assumes important responsibilities. If he locates his farm upon the fertile banks of a stream, on which he proposes to transport his wealth to market, he soon disturbs the subtle relations existing between its supply and discharge. If he follows the ravine up the mountain side and sinks a shaft, the accumulation of debris therefrom, unless removed, causes freshets

that will sweep him and his improvements away in a night. If, on a deep and safe harbor, he concentrates radiating lines of transportation, and establishes costly facilities for protecting and handling an accumulation of merchandise, he, at the same time, develops forces which will steadily impair the advantages which first attracted him. Nature will form no co-partnership with man. If he enters her virgin domain, to reap the advantages of civilization and science, he assumes the duty of replacing the natural status by his scientific care and forethought.

So the improvement of the navigation of the Mississippi river and the reclamation of the alluvial lands of its valley are not peculiar as engineering problems, because their theoretical treatment would be comparatively clear and simple were it not for abnormal complications arising from the disturbance of established natural relations. Could basins be built on its tributaries, to hold in reserve its supplies, to prevent their simultaneous discharge, to moderate the violence of excessive floods and at regulated periods to send down just sufficient water to keep the river in good boating order, and not enough to cause a velocity that would demolish the banks and levees, there is little doubt but that, in a few years, the river would permanently locate its bed in a succession of tangents and curves, determined by the equilibrium between its centrifugal momentum and the stability of the material of its banks.

That this condition was approximated, to some extent, before the settlement of the great valley is probable from historic facts relative to the increased magnitude of cavings and frequency of cut-offs, which will be given hereafter.

It is certain, however, that at this day the difficulties of the restoration of a better condition of the river are increasing. The enlarging area of cultivation has, by furrowing and breaking up the crust of the soil, made drainage and absorption more rapid and complete, by which greater floods are precipitated with more violence—has, by clearing the banks, deprived them of the protection of the thickly interlaced roots and the overhanging and trailing branches of the dense border growth—and has, by the extension of the levee system, had a tendency to raise the surface and increase the slope until a velocity is given before which the treacherous material of the banks wears and caves. Thus, while impetuosity has been given to the attacks of the floods, the banks have been deprived of the natural defences which their fertility reared for them.

The caving is immediately produced in two ways—which are characteristic of sand or clay bank. When the changes in the course of the river throw the force of the current against a bank of recent formation by deposit, it wears to a steeper slope than the limited tenacity of the material will maintain. This is the simpler and more rapid process.

When, however, the bank is of older alluvial formation it is found stratified with tough blue clay and flat horizontal pockets of quick-sand. shells or other treacherous material. Whenever one of these pockets is worn into, the contents exude from pressure, or are washed out by abrasion, and the leaf of clay above, deprived of support, breaks off and tumbles its load into the river. The profile of such banks shows the blue clay strata with an easy slope, and those of quick-sand or shells very steep, or even with an overhang.

An explanatory diagram accompanies this description.

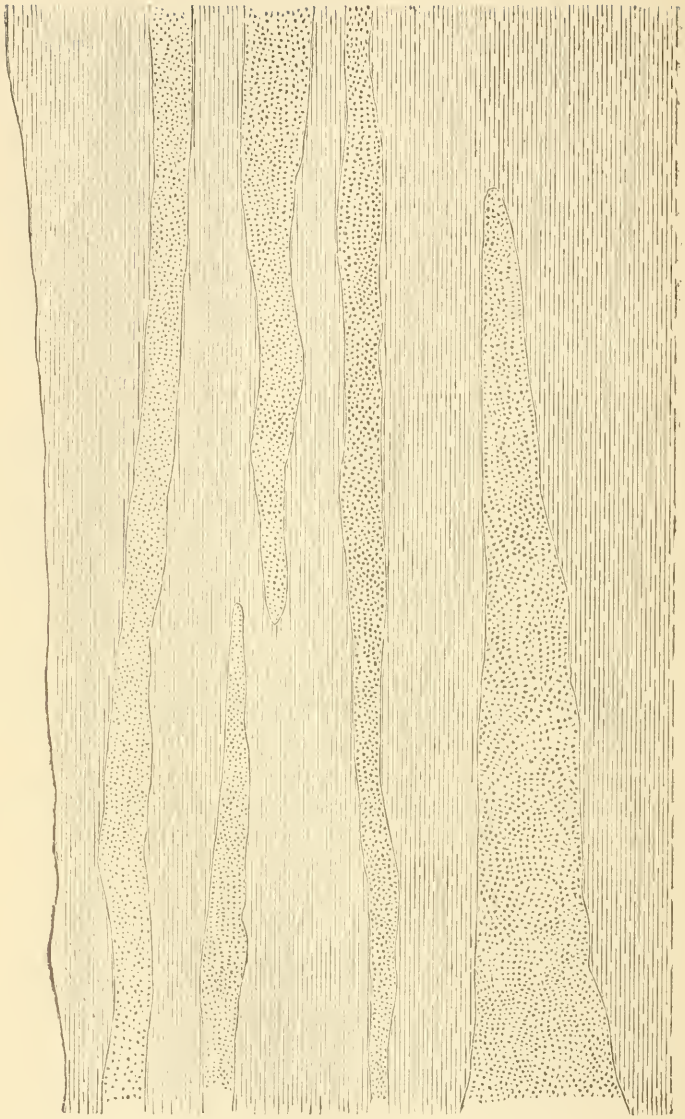
Thus, all the processes necessarily accompanying the settlement and cultivation of a new country have served to render more difficult of attainment the regimen which prevailed under the normal operation of the functions of nature, viz. : rainfall, surface drainage, absorption, slope, velocity, and discharge, and have given to the current of the Mississippi River an unnatural and destructive activity.

The curving banks which formerly served to turn the momentum with which the waters swept down have now been distorted by more rapid and excessive floods, which, deprived by levees of temporary relief from the swamp basins, have raised the surface, and increased the velocity to an extent that the banks are unable to resist.

At many points this process in the bends above and below has reduced the isthmus between, until it was no longer able to hold back the impending cut-off.

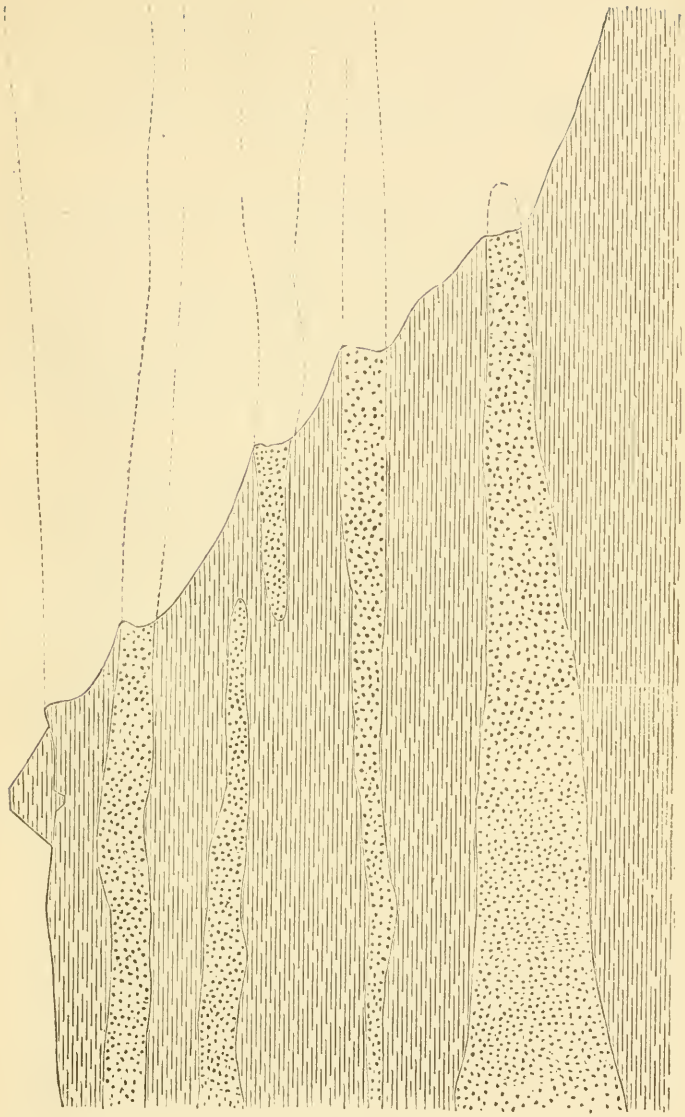
Thus a current already dangerously rapid from abnormally increased volume and slope is intensified by a reduction of length.

To this unnatural activity of the forces of the river, stimulated by a disturbance of regimen, and culminating in cut-offs, is to be attributed the deterioration of navigation and the destruction of levees. Notwithstanding the proof that causes have been at work to produce more rapid and excessive floods, and that the increased caving of banks, frequency of cut-offs, and obstructions to navigation are directly traceable to these causes, nevertheless. plans of improvement are seriously discussed which involve measures productive of a further increase of flood velocity and



SECTION THROUGH ALLUVIUM.

Lined Work indicates Clay. Dotted Work indicates Sand.



SECTION SHOWING ENCROACHMENT OF CAVING BANK OF RIVER ON ALLUVIUM.

volume, a prolonged contention with the river in its ceaseless effort to reduce its slope and recover its normal length, and delay and difficulty in the attainment of a regimen.

The existing functional derangement will be more readily appreciated and firmly established by the following facts in the history of the great river.

Many centuries are required to obliterate the traces of a cut-off. The earliest to which any date is attached is the Fausse Riviere cut-off of Pointe Coupee, which occurred in 1722.

The banks of this artificial lake are still well defined, and its waters, at the flood period, still connect with the Mississippi.

In the lakes and old rivers on either side of the Mississippi, from the Tennessee line about six hundred miles down to Pointe Coupee, we find the evidence of about twenty-eight cut-offs. Undoubtedly this record is complete for many centuries.

Yet of the twenty-eight cut-offs, nine, or about one-third, have occurred within the past forty-five years. This epoch of forty-five years has also been marked by two other important changes in the characteristics of the river: the clearing and leveeing of the banks for the greater part of this six hundred miles, and the extension of the bars and obstructed navigation from Plum Point, one hundred miles below Memphis, to Lake Providence, a distance of nearly two hundred and fifty miles, included in this six hundred miles where levees have been built and cut-offs permitted.

If these co-incident events do not establish clearly enough the connection between a disturbed regimen and the disasters to reclamation and navigation, let us examine a cut-off whose history is so recent, and whose record is so ruinous as to have attracted and fixed the attention of all observers of the hydraulic phenomena of the Mississippi River.

During the flood of 1867 the isthmus connecting what is now known as Davis Island with the Mississippi shore about twenty-seven miles below Vicksburg was broken through. The distance around this point was about twenty miles, throughout which the fall was about 3 inches per mile, or a total of five feet, which was condensed by the cut-off in the one quarter of a mile through the cut-off. Half of this increased slope was distributed down the river to below Glasscock's Bend, a distance of one hundred and fifteen miles, and caused a disturbed regimen and an accelerated velocity to which is attributable the follow-

ing record of ruin between the date of its occurrence and the present time. It is confined exclusively to the Louisiana shore. It is fair to assume that the Mississippi shore suffered equally :

Location.	Length in Feet.	Maximum Width in Feet.	Cubic Yards.	Acres.	Cubic Yards Levee.
Point Pleasant	11,440	6,160	100,000,000	1,075	383,801
Wilson's	8,800	2,640	30,000,000	330	320,962
Hard Times	14,000	1,000	15,000,000	175	496,791
Boudurants	30,000	10,000	25,000,000	300	242,615
St. Joseph	15,000	3,000	40,000,000	500	44,986
Kempe	16,000	5,000	100,000,000	1,250	1,315,495
Waterproof	18,000	2,600	25,000,000	300	497,296
Marengo	25,000	5,000	120,000,000	1,500	366,075
St. Catherine's Bend	10,000	2,400	20,000,000	275	114,339
Glascock's Bend	38,000	2,000	75,000,000	850	732,960
Total	186,240		550,000,000	6,555	4,515,320

In this table is not included the levee work done by parties other than the State Engineers, which is of a considerable amount.

No details are given of the damage above by this cut-off, although it was equally evident and extensive, because it was confused with that caused by the Terapin Neck Cut-off, which occurred in the previous year about sixty miles above Davis Island.

These reflections on the causes and magnitude of the difficulties to be encountered in securing the unbounded wealth of the Valley of the Mississippi, disclose the outlines of a plan by which they can be encountered and defeated.

This, or any other plan, must, however, be adopted under the explici and intelligent recognition of two inevitable complications :

1st. The continued clearing for cultivation of the banks of the Mississippi and its tributaries will continue on the most extensive scale ; and

2d. The levee system will be pushed to completion. The first o these obstructive elements is practically unlimited in its duration. The second is not so. It is purely a financial question whether the system shall be completed in two or twenty years.

But inasmuch as the extended construction of levees will have a tendency to disturb the regimen whenever it may be undertaken, they should be eliminated from the problem at the earliest possible moment, and a complete levee system should be assumed as the first step in all projects

of improvement. A judicious location of these works will allow for sufficient prolongation in the bends to give the required reduction of slope, and will be governed by the experience of the engineer, and formulæ, in which the volume and velocity, increased by the completion of the projected work, and the angle of incidence, are opposed to the stability of bank, as composed of clay or sand.

The necessary height has never yet been determined by experience, for great floods have always found a point, vulnerable from carelessness or fraud, before they culminated.

The height recommendations of the U. S. Commission of 1874 are more than safe, for while all the elements of danger are recognized, no credit is allowed for hydraulic principles as well established as those on which are based their precautionary recommendations. Thus, whenever the retention of all the water within the levees would require that they should be built eleven feet higher at Lake Providence than the flood of 1858, then the depth would be increased eleven and one-half per cent., the volume in a still greater proportion, and the slope upwards of eight per cent. from Lake Providence where the flood wave culminates to zero at tide water. These new factors would generate a velocity and discharge that would forbid the verification of the estimated increase of flood level.

With the completion of the levee system, the question of outlets loses most of its importance. The objections to new ones consist in the greater slope required for a smaller volume, and in the continuance of the present disturbance of regimen. Of those now existing the Atchafalaya is now mainly supplied from Red river, the Lafourche is of insignificant dimensions, and the Jump and Cubits crevasse are too near the mouth of the river to affect the levees or navigation.

But certainly the most important measure of all for securing the great objects proposed is, the absolute prevention of "cut-offs" at any cost, by the thorough *revetment* of the approximating concave banks.

Subsequent measures must be conservative, tending to remove all disturbing elements. Among them may be mentioned the encouragement of a dense growth on the banks between the levee and the river.

The penalty of any forcible treatment is immediate reaction on the weakest part of the bed. Before it will be experimentally ascertained whether the bottom is of clay, "almost like marble," or whether "it will not resist the incessant action of the current," the banks will be

melting before the increased current unless protected by miles of revetment which the experience at Cairo, and the estimates at Memphis, Vicksburgh, and New Orleans show will cost $100,000 per mile.

In the report of Col. Simpson. U. S. Engineers in 1875, on the improvement of the navigation of the Mississippi river, the outlines of a system are given with clearness and ability. It is established that the low water channel referred to in speaking of the improvement of navigation and the line of greatest flood depth do not coincide, nor is it the result of the operation of the forces of the previous flood. On the contrary the subsidence of the flood leaves the channel in an impaired condition, obstructed by a succession of sand waves or bars. The crests of these bars mark the thread of the flood current by their composition of the heaviest material. The feeble forces of low water avoid this line in excavating their channel. It is therefore, important that the scanty resources of the river at this season should be carefully husbanded, and that works designed to aid in establishing a low water channel should not increase the flow over a bar, lest obstructions higher up the stream be developed. The effort should be to give a more efficient working section to the channel while preserving its capacity of discharge.

It would appear that the conclusions to be drawn from the foregoing remarks are, that the first work to be done on the river is the prevention of cuts-off and the completion of levees. Then, under this discipline, the river should be allowed to acquire the relations of slope, length and velocity imposed upon it by hydraulic law.

This condition will be comparatively permanent, and, under it works for the improvement of its navigation can be pushed with impunity under a system that combines with the scouring power of an accelerated current, proper precautions to protect the treacherous banks, and direct its action against the bottom. Let it never be forgotten that "a great river is impatient of restraint; it can be led, but it cannot be driven."

AMERICAN SOCIETY OF CIVIL ENGINEERS.

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CLXX.

(Vol. VII.—September, 1878.)

BRICK ARCHES FOR LARGE SEWERS.

By R. HERING, C. E., Member of the Society.

Read at the Tenth Annual Convention, June 18th, 1878.

The City of Philadelphia, having many miles of large brick sewers with diameters as great as 20 feet, offers a favorable opportunity for studying, among other interesting questions, the stability of arches with long axes. And it has been especially facilitated by the occurrence of some failures, such as flattening at the crown, and spreading at the spring, or entire collapse. The usual design was a circular ring of brick, held in position by abutments, and spandrel filling of rubble masonry, the dimensions being calculated according to the ordinary empirical formulæ. An inquiry into the conditions of stability by means of the method of Graphical Statics showed that even with a fair execution some of the arches could not permanently resist the pressure. Instead of increasing the dimensions, a careful study led to the adoption of a different plan, especially for cases where the horizontal thrust cannot at first be safely resisted by the earth on the sides, but must be taken up by the abutments, and transferred to the foundation. During

the last two years several miles of arches from 5 to 20 feet span have been built according to this plan and under these conditions, with perfect success.

As the construction is somewhat different from the usual practice, I believe it a proper subject for discussion.

Before stating the main points, I will describe two breaks in our largest sewer, built about seven years ago, and point out the reliability of the principles which form the foundation for the present design, by comparing theoretical conclusions, as far as possible, with the practical results.

Fig. 1 (Plate XXXII) represents a half-section of the Mill Creek sewer 20 feet in diameter at the spring. The dotted lines in the arch represent the original section and the full lines a section as standing adjacent to a break. The semicircular arch is built of two concentric rings of brick, and the abutments are built of rough rubble masonry, shaped as shown in the figure. The workmanship was not of the best; the mortar is poor and scanty. Testing the original design by drawing in the line of pressure (indicated by a dash-dotted line) from the diagram of forces in Fig, 1*a*, it will be noticed, after equalizing the danger of breaking at all the joints of rupture, that this line is not confined to the kernel of the section, that is, the middle third of the joint area.

What will be the result?

When the centre of pressure falls within the kernel, the neutral axis lies outside of the section, and causes compression on the whole area. As it passes out of the kernel, the neutral axis enters the section, when tensile strains, acting on one side, will tend to crack the mortar and open the joints; and the compressive strains, acting on the other, and being resisted by a smaller area, will cause a proportional increase of the unit strain.

Now, in Fig. 1 the line of pressure intersects the joints of rupture at the crown and haunches of the original design at $\frac{1}{10}$ of the thickness of the section, locating the neutral axis at $\frac{3}{10}$. Therefore, $\frac{7}{10}$ of the section are under tensile strain, while all the compression is confined to the remaining $\frac{3}{10}$.

The existence of the *tensile* strains can be seen on the work in the actual opening of a part of the joints of rupture at the crown and haunches, as indicated in the figure. As the strain in the most com-

pressed fibre is twice as great as the strain per unit of joint area,* we can also readily examine into the condition of *compression* at those joints. From Fig. 1*a* we measure the thrust at the joint of rupture in the haunch as 13 900 pounds per running foot. The pressure being distributed over $\frac{3}{10}$ of the section, or $5\frac{4}{10}$ inches, will give a strain of $\frac{2 \times 13\,900}{12 \times 5\frac{4}{10}} = 429$ pounds. According to Trautwine, cracking and splitting of brickwork occurs at about 400 pounds, which shows an unsafe condition in this case. And, as this strain proportionately increases the nearer the line of pressure approaches the edge, we should justly expect to find extensive chipping of the bricks near the theoretical joints of rupture in the section drawn out with full lines. An examination of the sewer, where this section is approached at many points, shows it to be actually the case.

The result of the original position of the line of pressure then, will be a constant tendency of the arch to rotate at the joints of rupture in a direction from the compressive to the tensile strains, thereby causing a sinking at the crown and a pushing out at the haunches. This change of form has also taken place in a greater or less degree throughout the whole sewer.

Lastly, the bed joints of the rubble and brick masonry at the springing line deviate from twenty-five degrees to twenty-nine degrees from a perpendicular to the line of pressure, showing an unsafe resistance against sliding, especially as the masonry was poorly built. The horizontal thrust has therefore very generally caused a spreading of the arch, though it is not indicated in the figure.

Fig. 2 represents a half section of the Cohocksink Creek sewer, with a horizontal diameter of 18 feet 6 inches. The arch is elliptical and built of brick, with a thickness varying from 18 inches at the crown to 3 feet at the spring, and the abutments are built of rubble masonry, as shown. The original section, marked with dotted lines, has changed its shape more or less, and adjoining a break it appeared as shown by the full lines. The workmanship, materials and mortar were good. It was built about eight years ago.

Testing this design by drawing in the line of pressure from the diagram of forces in Fig. 2*a*, the same discordance with the laws of stability will be found as in Fig. 1.

* See Woodbury's Theory of Arches and Culmann's Graphical Statics.

The line intersects the joints of rupture at $\frac{1}{6}$ of the thickness, instead of at $\frac{1}{3}$, locating the neutral axis in the middle of the section; therefore, the constant tendency to rotate has here also caused the crown to settle and the haunches to push out. As the weight over the arch, however, is much less than in Fig. 1, the thrusts are smaller, and the centre of pressure can approach the edge closer before the bricks are crushed, which in this case would occur at a distance of about $\frac{2}{3}$ of an inch from it.

Cracking and splitting of the bricks can be noticed all along the theoretical loci of the joints of rupture, and likewise the corresponding openings on the other side of the neutral axis, as shown in the figure, and as theory leads us to expect.

Finally, the line of pressure intersects the perpendicular to the bed-joints in the springing at a larger angle even than in Fig. 1. As the resultant at that point is 9 800 lbs., and assuming the co-efficient of friction for masonry to be .6, we find a horizontal resistance of only 5 880 lbs. against the horizontal thrust of 5 590 lbs. And this small excess of 290 lbs. is more than balanced by the pressure of water, when the sewer is running nearly full, which always occurs during a heavy storm at high water. Consequently, the entire sewer has spread from 6 inches to 12 inches, until the earth on the sides has become sufficiently compact to prevent further movement and to resist the line of pressure at a higher point.

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Such failures as shown by these two sewers, and the fact that the conclusions arrived at from the application of the method of Graphical Statics were so truly confirmed by the actual results of our experience, led us to adopt a different design, which it was intended should be based entirely on principles of this method.* In arranging it, the following main points were carefully considered:

I.—At no point should the material be subjected to more than a safe fraction of its ultimate crushing strain. Assuming the safe resistance of brickwork at 80 pounds per square inch, a very convenient formula has been:

$$\text{Least thickness of arch in inches} = \frac{\text{Pressure at joint of rupture in lbs. per running foot.}}{480}$$

which is deduced from the fact that the strain in the most compressed fibre is twice as great as the average strain per unit of joint area.

II.—The bed joints of the bricks and stones should everywhere be as nearly as practicable at right angles to the direction of the line of support, and not deviate from it more than a safe fraction of the resistance against sliding will admit.

III.—The line of pressure must be situated in the kernel or middle third of the arch, to prevent any tendency of rotating. It must also intersect the foundation at a point sufficiently far from the edge to be safely resisted, on account of the rough nature of the rubble work.

When the earth on the sides is solid enough to resist the resultant of pressure, it can of course take the place of the abutment, and the pressure line does not require to be enclosed in mason work down to the foundation, but can pass out into the earth at any point.

IV.—The different materials should be disposed of in such a manner that each may serve for the purpose to which it is *best* adapted.

The necessity of carefully curving the line of pressure in the arch demands well defined joints, thorough bearing surfaces, and homogeneous masonry. Therefore, well-built brickwork, being the best for this purpose in our case, was planned to resist alone the entire pressure, as far as it is curved. When it becomes practically straight in the abutments, and distributed over a larger surface, rubble masonry will then answer perfectly. As the spandrel filling has no other duty to perform, according to theory, than to furnish a uniform vertical pressure upon the arch, earth alone, when well compacted, can entirely fulfill it. The gain of a greater weight by using rubble masonry and thereby slightly reducing the width of foundation, may sometimes be economical, but it is usually more than balanced by its own greater cost. If the rubble masonry is to take part in resisting the line of pressure, it can only do so when forming an auxiliary arch of itself, outside of the brick arch ; otherwise it acts only as weight. Wherever the filling is light, and the live load great, stone spandrels would *stiffen* the arch against a concentrated pressure. But this extra stiffening is not necessary where the live load can be neglected in the calculation, as is usually the case.

V.—The brickwork is to be bonded, so that the line of pressure will pass through the middle of headers as much as possible, to prevent separation of the rings.

The design resulting from the consideration of these five points is shown in Figs. 3, 4, and 5, which represent three sewers, built one and two years ago. A careful examination during construction, and since, shows

perfect stability. No cracking at the crown, chipping of bricks at the haunches, nor change of original shape have taken place.

Besides seeming to be a more rational distribution of the material, and therefore more reliable in its stability, this plan is also more economical, as it requires less material to give the same strength as the old one. To secure these advantages, however, the abutments must be built carefully and solidly, so that there is no possible uneven settling, which might cause rotation around the springing line. The ring joints in the brickwork, as well as the others, must be well filled with mortar to prevent separation; and the earth filling in the spandrels must be uniformly and well compacted in order to answer the supposition of theory that the entire weight acts like its supposed resolution into separate weights as indicated by the division into vertical laminæ.

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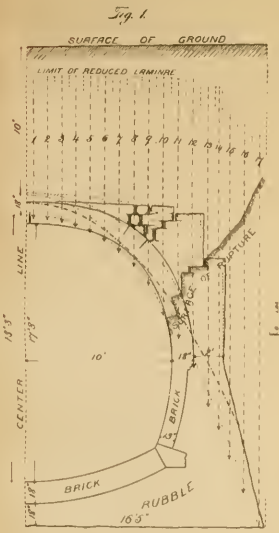
DISCUSSION ON PAPER CLXX.

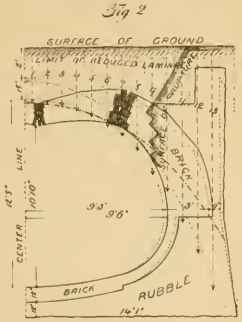
BRICK ARCHES FOR LARGE SEWERS.

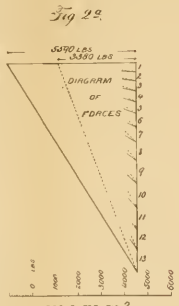
By E. S. CHESBROUGH, W. MILNOR ROBERTS, R. HERING and F. COLLINGWOOD.

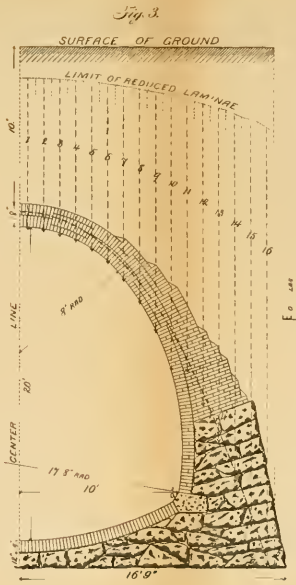
E. S. CHESBROUGH:—Mr. Hering has sent me two sketches with a brief statement of the main points of difference between the "old" and the "new plans," from which I learn that in some respects the mode of constructing sewers in Philadelphia has been peculiar. I am ignorant of the circumstances which led to the introduction of the "old plan" at first, but it seems strange to me that it should ever have been adopted for general purposes, whatever might have been advisable in some special cases. The "new plan" is substantially that which has been known to the profession, in connection with the stability of arches, for a long time. The arrangement of the joints between the arch stones, placing them at right angles to the line of pressure if that line can be readily determined, must be of decided advantage. If the sketches sent me are drawn to a scale, the thickness of the arch was too light, by the "old plan." The arches of the large London and Paris sewers were made

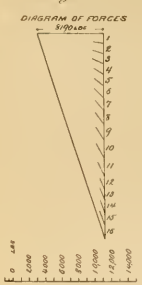
BRICK ARCHES FOR LARGE SEWERS.

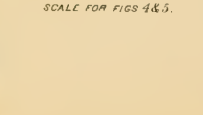


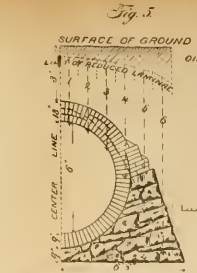


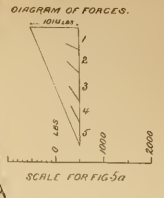


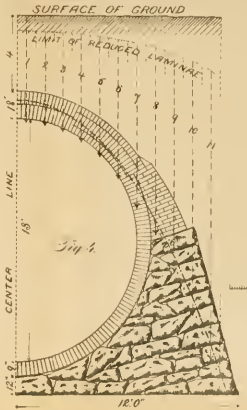


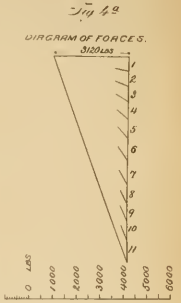












much thicker than those of the Philadelphia sewers. On the other hand, many, if not nearly all of the older London and Paris sewers have far less backing, or masonry outside of the arches, and it seems strange that so much should be needed in Philadelphia, unless the peculiarity of the soil requires it.

When sewers are laid deep enough to be beyond the disturbing influences of other works, and are built in simple arches of sufficient thickness and good materials, they have been known to stand without change of form, for generations, with no backing of masonry. The necessity for this, if it exists, must be determined by the circumstances of each case. It is not only an extra cost in itself, but requires additional cost for excavation, back-filling and repaving.

W. Milnor Roberts :—More than a year ago I examined Mr. Hering's plan, and his arrangement of the brick arch and haunches in connection with sewers in the City of Philadelphia, having diameters of 13 feet, 15 feet and 16½ feet, respectively, and I was satisfied that it was safer than the plan of the Cohocksink Sewer, which I had occasion to examine at a point where it had failed, and where the arch had fallen. I also had occasion to examine the circular sewer, nearly a mile in length, in which occur the diameters of 13, 15 and 16½ feet.

I understand Mr. Hering to limit the whole question to the case where the earth on the sides is originally not firm enough to resist the resultant of pressure ; where masonry abutments of some kind would be required.

The brick inverts of these circular sewers were of the thickness of one brick, lengthwise, and these were laid upon a cradle of rubble masonry extending laterally to the outside of the rubble abutments, and outside of the line of pressure of the arch. I did not consider that any rubble masonry was needed below the lowest part of the brick inverts, where the sewer rested upon a solid timber and plank foundation. I deemed it an injury, rather than an advantage ; but that does not necessarily affect the question of the stability of the arch and its abutments. If I had planned a double sewer, where the twin 13 feet sewer is built, *upon a solid platform*, I would not have had circular sewers at all ; but semi-circular arches of a little less span, with side walls.

Where semi-circular arches rest upon abutments, without inverts, it is true, there is a greater pressure transmitted from the arch through the abutments than where inverts are used ; to the extent, of course, of

whatever portion is transmitted through and sustained by the inverts; but there is no saving in the quantity of masonry; because the brick invert, *in the case in question*, has to be supported between the middle of the sewer and the abutments proper by masonry.

Not being called upon to do so, at the time I examined the fallen Cohocksink sewer, I made no special investigation as to the immediate or proximate cause or causes of its failure. Mr. Hering's exposition of what he believes was the cause appears to me to be sustained by his theory.

I was satisfied at the time, and I am still satisfied that Mr. Hering's arrangement of the brick work was much stronger than sewers of the dimensions mentioned are usually built, but at the same time I expressed the opinion to Mr. Hering that the top course of brick which he had added was unnecessary; for the reason, that the arches, according to theory, and according to my experience in practice were thick enough without it.

That which I approved of was the principle of somewhat increasing the thickness of the regular brick work on the haunches so as to bring the line of pressure and maintain it near to the middle of the brick masonry, and so as to diminish somewhat the quantity of the rubble masonry abutments near the top. I also approved of the arrangement by which the bed-joints were laid nearly perpendicular to the pressure line in the middle third of the brick work. Bonding the bricks so as to throw the line of pressure through header courses to prevent separation of rings is also an advantageous arrangement, adopted by Mr. Hering.

An equilibrated arch may not be a circle on the intrados, if the structure be required to sustain a heavy dead load, level on top, which is sometimes the case with sewers; but the sewer being circular, with an invert, the arrangement of Mr. Hering's seems to be an approach to equilibration; having little tendency to break in one part more than in another, and is on that account commendable.

R. Hering.—In reply to Col. Roberts, I would like to state that the thickness of the arch in Fig. 1, was determined by some old empirical rule, and as my examination has shown, and as Mr. Chesbrough writes, it is too light. The increased thickness in the new designs, which Col. Roberts thinks was unnecessary in one case, is in exact accordance with the latest empirical formulæ of Trautwine, Rankine and others.

The safe working load for brickwork is given all the way from 80 to 280 pounds per square inch. We have been assuming it at 80 pounds, and find this satisfactory

F. Collingwood.—Our experience on some small brick arches in the approaches of the East River Bridge confirms what Mr. Hering has said in reference to the use of headers rather than of ring courses in an arch. I am inclined to think that a judicious study of the band to be employed is *quite* as important as the discussion of the general form.

No doubt many of you read some time ago of the failure of a small brick arch in the Brooklyn approach whereby one man lost his life. After the accident I was called upon to make a critical examination and report upon the same.

The general arrangement of that work is a series of heavy piers about 100 feet long, and faced with stone, and running across the bridge. These piers are to be connected by heavy arches over which the roadway is to pass. Each pier is to be a double arcade of ten arches, five on each floor. A portion of these are shown in the drawing on page 263, and it was the arch ($a\,b$) which failed.

The arch had a span of 13 feet; rise, 16 inches, and thickness of 20 inches; and was laid up in five distinct rings of brickwork, or built "rowlock," as it is called. The length of the axis was 6 feet. It abutted on limestone skew-backs, and at the time of the failure about 8 inches of brickwork above the crown had been laid on nearly uniformly. The abutment for 11 feet below the spring was 7 feet wide and 6 feet thick down nearly to the line ($f\,d$).

At the time of the accident the masons were at work on top of the arch, when the foreman saw a crack open across the top of pier at (b). He instantly warned the men and they ran to the ladders. By the time they had descended to the floor below, the end (b) had settled about 6 inches, and was turning on (a) as a pivot. By the time they reached the ground the arch was falling. It struck the lower arch and broke it in two, and all fell together, leaving the abutment ($g\,a$) standing, but showing cracks, approximately at ($c\,d$) and ($g\,h$), (I have lost the sketch I made at the time). A movement of an inch was probably enough with the crushing of the mortar which would occur, to let the arch slip through.

After making a careful computation of weights I applied Dr. Scheffler's graphical method, taking first the case where the line of pressures was everywhere within the middle third. This line pierced the line $d\,f$ at

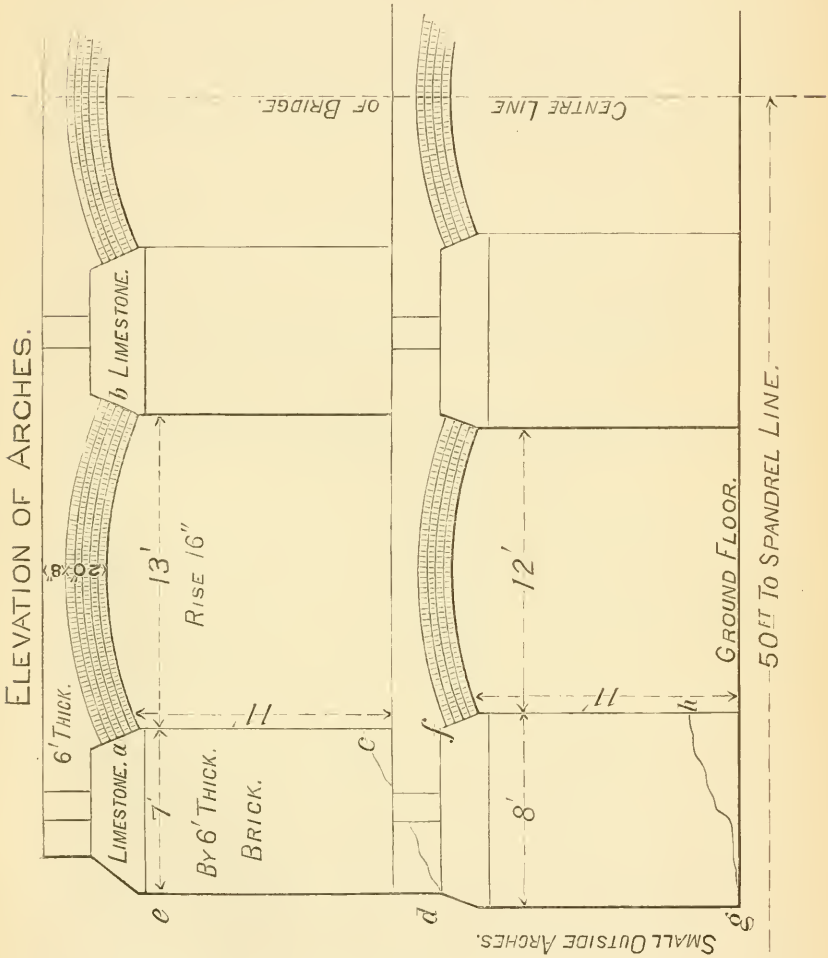
about 13 inches only from (*d*); and by trying the moments of the thrust and the pier at *d* as a centre, they were about as one to one and one-tenth. Trying the possible case of the line of pressures approaching to within two inches of crown and two inches of intrados at spring (as the brickwork would still be strong enough to resist crushing, the pressure being but 50 to 60 pounds per square inch if resisted by one ring only), the line of pressures fell within the base at the *ground floor;* and the moments about *d* were about as 1 to $1\frac{5}{10}$. As this brickwork had been set in strong cement mortar it had considerable strength as a beam; and I considered the investigation as proving thus far, that failure could not have occurred by the arch acting as a whole.

There was no evidence of compression in the outer joints of the abutment. There was, however, some evidence of the bricks just below (*a e*) having slipped a little on their beds while the mortar was but partly set. This led to the supposition that there might have been just enough movement to leave but a partial bond or adhesion of the mortar between the several rings, and that they had acted more or less as a series of arches. In *this* case the line of pressure could *not* have passed from ring to ring, but the resultant of all would be approximately through the central ring. Trying *this*, I found that the thrust would be nearly double, and the resultant pressure would run out a little above the line (*d f*). The slowness of the movement shows that the abutment was barely overbalanced. Other piers precisely similar had stood. The centre had been removed probably a little too soon, although it had stood two or three days and did not fail until the men were working on it; but I am satisfied in my own mind that the arch would *probably* have stood had it been bonded through sufficiently to transmit the thrust from one ring to the next.

Mahan says: "The entire arch should be divided into several portions, by joints running entirely through from the soffit to the back, the brick being laid in these successive portions in shells (or rings); and in blocks, with joints running *entirely through the arch from the* soffit to the back. Any bond may be adopted for the portion laid in shells. The blocks in which the joints run entirely through should not consist of more than three or four bricks in thickness, estimated along the curve of the soffit."

In other words, he would form masses which would approximate in form to the voussoirs used in stone work, with thinner strongly bonded masses between them.

I ought to say before closing that the exterior arch abutting against this is abundantly strong to take all thrust, and that *this* arch would probably be safe itself when it had the weight of the main arch and roadway upon it.



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CLXXI.

(Vol. VII.—September, 1878.)

FALL OF THE WESTERN ARCHED APPROACH TO SOUTH STREET BRIDGE, PHILADELPHIA, PA.

By D. McN. STAUFFER, C. E., Member of the Society.

Read September 4th, 1878.

It is a well-accepted engineer's maxim that failure is more instructive than success, and if the following account of the disaster at South Street Bridge proves interesting to engineers generally, and serves as a warning to the younger members of the profession, the purpose of the writer is fulfilled.

The lesson specially taught by this experience adds but one other to the many preceding it, and treats of the vital importance of an exhaustive examination, *at any cost*, into the material underlying foundations.

In this particular case "economy" in the preliminary explorations caused the complete failure of otherwise exceptionally good work.

The description is as much in detail as possible for the writer to make it, for though he was the engineer in charge of the original construction, his connection with the bridge was entirely severed on its completion in February, 1876. Since that time the work has been in other hands, and he can only describe what happened after his departure from such data as he could gather from those now connected with it.

The portion of the bridge destroyed was made up of nine segmental stone arches—43 feet 6 inches span and 14 feet rise, with a width of 55 feet. The arch piers—eight in number—were 55 feet long, 5 feet 6 inches thick and 12 feet 6 inches high. These piers were built of granite ashlar, in courses 17 inches to 26 inches rise. The masonry foundation under the piers was 9 feet high, with a base of 10 feet by 60 feet, the material limestone. The arches were laid in hard brick; they were 24 inches thick, with ringstone and skewbacks of granite. The haunching was limestone rubble masonry, and was carried up level with line of intrados of arch at the crown. The spandrel walls were limestone, faced with Trenton sandstone ashlar, and were surmounted by two 12-inch granite coping courses. All masonry was laid in hydraulic cement mortar, the brick arches in one cement to one sand, all other portions in one cement to two parts sand. To obviate settlement, a considerable portion of the filling in between the spandrel walls was small stone and quarry refuse; the remainder was gravel. North River flagging was used for the footwalks and granite for the curb. The roadway was laid with granite blocks.

These nine arches and eight piers fell, Sunday morning, February 10, 1878, the original cause being the sinking of some of the piles under one arch pier.

The ground underlying this approach is an alluvial deposit—treacherous and unstable in character; it is flooded to a depth of about two feet at high tide.

At the west bank of the Schuylkill this deposit is about 60 feet deep to the rock beneath, (a micaceous gneiss). The rock rises rapidly toward the west, and comes very nearly to the surface at a point just west of the arched approach. Overlying the rocks is a stratum of very hard gravel, about 20 feet thick at the river, and above this gravel is mud, which becomes more dense as the depth increases, passing into a tough clay before it reaches the gravel. Running through this mud deposit at different depths are strata of very hard gravel from six to eighteen inches thick.

Soundings were taken over this ground with a pointed iron rod, screwed down by the combined effort of four men, applied to an iron adjustable cross-bar bolted to the rod. With this apparatus it was impossible in all cases to reach the rock, owing to the extreme hardness

of the gravel strata. At the river the depth to rock was arrived at by data obtained in sinking the pneumatic cylinders forming the river piers.

"The want of an appropriation for any such purpose," unfortunately prevented a more thorough and elaborate investigation by means of "test wells."

When the writer was appointed engineer in charge, in 1870, he found a contract already entered into and work commenced on the plan of approach described. The specifications of the contract called for "pile foundations or timber platforms," when rock was not obtainable.

Numbering the arch piers from the west toward the river, the west abutment and Pier No. 1 were on timber platforms on gravel, the gravel stratum rising very rapidly between Piers Nos. 2 and 1. Pier No. 2, the settlement of which caused all the trouble, and Piers 3, 4, 5, 6, 7, 8, and the river abutment, were founded upon piles.

After piles of pine and oak had been shattered by the effort required to drive them through the thinner strata of hard gravel spoken of, Nova Scotia spruce pine was adopted. This timber is very tough and difficult to split. "Bands" and "shoes" were discarded, being found unnecessary, and, as affording a better base, the toe of the pile was not pointed. The piles were from 12 inches to 18 inches in diameter at the butt, and from 46 feet to 24 feet long, when "cut off." The longest piles were of course used nearest the river, and were the first driven. The shortest piles were under Pier No. 2, and the last driven. The pile driving was finished in September, 1870.

A steam "pile-driver" was used, with a 2,000-lb. hammer, and a 32-feet "drop." The only test as to the stability of the pile when driven was to persistently hammer away, until, after the repeated trials, it was found impossible to force the pile any further.

There were eighty-four piles under each arch pier—four rows of twenty-one piles each—spaced two feet apart from centres. These piles were cut off two feet below low-water mark, and the material excavated from between them to a depth of two and one-half feet below the heads, and this space filled with concrete. A sixteen-inch hemlock grillage, made up of two tiers of eight-inch stuff, from twelve to sixteen inches wide, was bolted to the tops of the piles, and all interstitial spaces likewise filled with concrete. Immediately supporting the foundation masonry was a platform, built of two courses of 3-inch hemlock plank,

spiked diagonally to the grillage and crossed. The dimensions of the platform were 60 feet by 10 feet, and, including the concrete, it was 4 feet 4 inches thick. The foundation masonry under the pier was limestone rubble work, very large and well-shaped stones being used.

The greatest load that can be assumed as being carried by the piles under any one of the arch piers is 2,000 tons; and this load, distributed over eighty-four piles, would give about twenty-four tons per pile, little more than *one-half* their safe load, assuming the piles to be driven to a solid foundation.

And just here we might mention that under the mischief-making Pier No. 2 the piles were driven the same as they were under the other piers—until they would penetrate the soil no further. The platform on the piles was a very stiff one, and a light load was imposed upon each pile. When the foundation was completed there was no reason to doubt its stability, for it was supposed that the hard driving to which the piles were subjected would more than counterbalance the absence of "test-well" exploration, prevented by want of funds. The mechanical force of the blow of the hammer was more than the permanent load upon the pile. The material through which the pile was driven was, from the very surface, impervious to water, and the lower portions of a nature to guarantee a very considerable frictional value. Yet, notwithstanding all this seeming safety, the piles under one end of Pier No. 2 did, finally, sink, after supporting their full load for six or seven years, for reasons given further on in this article.

As previously mentioned, the writer left the bridge upon the completion of the work in 1876, and has since been employed on other and distant work. Having his attention called to the sinking of one of the arch piers by articles in the public press, he visited the bridge on February 7th, 1878, and found that the trouble was all confined to the north end of Pier No. 2, all other portions of the arched approach being in perfect condition. Pier No. 2, it is reported, first began to show signs of failing in the early part of 1877. In about one year—to the date first given—the north end of the pier had settled twenty inches below its normal position. The south end practically stood firm, the south coping and handrailing showing no disturbance whatever in line or level. Owing to the stiffness of the platform, the arch pier and its foundation masonry was sinking as a mass, none of the mortar joints in the pier being cracked, either horizontally or vertically. The skewback

preserved a straight line, as shown by the heavy black line on Plate XXXIII. The foot of the pier had pushed about six inches to the south, thus making it appear as if the platform and foundation and pier masonry were revolving about a point located in the south face of the approach, above the springing line of the arch.

A single crack was apparent in the intrados of each of the brick arches adjoining the sinking pier, making an angle of about sixty degrees with the plane of the springing line. These two cracks were confined to the northern half of the arches, and were not more than half an inch wide at their widest point. The southern half of the arches appeared to be perfectly sound.

Over the north end of Pier No. 2 the mortar joints in the spandrel were badly crushed, and some of the face stones broken, under the pressure. The two coping courses, and with them the footwalk curbing, and one-half the roadway, had settled twenty inches at the lowest point, the settlement taking the form of a regular curve, and extending each way from the centre line of the pier to a point nearly over the crown of the adjacent arches.

On Saturday morning, February 9th, 1878, workmen came upon the ground to commence the much needed repairs. One party began to frame struts, to be set up under the sinking arches, on some plan unknown to the writer. But another gang, before these struts were even partially in place, with very questionable wisdom, commenced to remove the flagging, curb and Belgian blocks over the northern half of Pier No. 2.

According to the statement of the men engaged upon this work, they found this material subjected to great pressure, and, naturally, they experienced great difficulty in displacing it. They say this was done with the idea of reducing the rate of settlement and gaining time, by getting rid of some of the superincumbent weight.

As to what "this rate of settlement" was, having no personal knowledge, the writer can only quote from a published letter of the Survey Department, viz.: "Levels taken six days prior to February 10th did not "show any appreciable difference from those taken three days before; "but from the fifth to the eighth the settlement per *day* increased from "three hundredths of a foot to seven hundredths of a foot. On the "afternoon before the fall it sank from two to three hundredths of a "foot per *hour*, the last twenty-four hours amounting to six-tenths of a

"foot." The words "day" and "hour" are not italicized in the original letter, but show a very sudden and rapid increase in the settlement on Saturday afternoon.

About 7 o'clock on Sunday morning, February 10th, the crippled arches gave way at the haunches and fell; and, there being no centres, ties or supports of any kind under any of the arches, the seven sound arches immediately followed, all falling toward Pier No. 2.

The masonry in the approach was very good, as the ruins testified; portions of the brick arches 10 and 12 feet wide, and 30 feet long, fell to the ground, a distance of about 30 feet, without shattering; some smaller pieces of the arch were turned completely upside down, showing the intrados on top as they lay.

A short time after the fall "test-wells" were, after much trouble, sunk to the rock around Pier No. 2, and from those employed on this work the following data were obtained:

Thirty feet north of Pier No. 2 the rock was found, thirty-three feet below the surface of the marsh; at the north end it was forty feet to the rock; while at the south end of the pier the deposit was thirty-six feet deep to the bed rock; thus making a depression in the profile of the rock just under the north end of the pier. Covering this depression was a bed, about three feet thick, of soft mud, mixed with gravel, and over this a stratum, seven feet thick, of very hard gravel and tough clay. At the south end of the pier there was no mud, and the gravel stratum was reduced to a thickness of eighteen inches. From the gravel to the surface the material was mud—quite soft at the surface, but passing into a tough clay some time before it reached the gravel. This upper mud stratum was impervious to water, no pumping having been required in laying the original foundation, unless a gravel vein was tapped or water came in from the surface. An inspection of the accompanying plan will make the above more clear.

These soundings make plain the original cause of the failure, and explain one of the "mysterious" features of the case—why the pier should sink, after standing for six or seven years.

Unfortunately, the exact length of each pile, as driven and cut off, cannot now be ascertained, for the contractor was paid "per pile," and not per "lineal foot." But it is a matter of record that the piles under Pier No. 2 were from 28 feet to 30 feet long as hoisted into the "driver," and that the "average length" of the 84 piles, as cut off, was 25 feet.

The want of this exact data makes it impossible to show in the diagram how near the mud the piles at the north end were actually driven.

The writer's theory to account for the stability of the structure for a period of years before failing, is as follows: That at the south end of Pier No. 2 the piles were driven almost, if not quite, to the rock, there not being a sufficient thickness of hard material to prevent this being the case, and, as a consequence, that end stood firm; but at the north end of the pier, under the heavy driving, the piles penetrated almost *through* the hard stratum, say to within two or three feet of the upper limit of the "mud pocket." When this point was reached, the direct and frictional resistance was sufficiently great to prevent further penetration. Just what this frictional resistance was, can, under the circumstances, be only estimated. Rankine's rule, would give, as here applied, about 8 tons per pile. Be this what it may, from the nature of the material, it must have been considerable; and events prove that there was a sufficient amount of hard material between the mud and the toe of the pile to support the structure for a long time.

But the tremor in the piles produced by the heavy and constant travel over the approach was in this case an element of destruction. This tremor had a tendency to loosen the pile from the impervious material into which it was driven, and allow the surface water to slowly find its way down along the pile. In time this water would "lubricate" the pile and destroy the frictional value of the mud, and constantly add *additional* load to that originally carried by the toe of the pile; which original load, we will say, was in this case 16 tons. Possibly, before the whole of the 8 tons (previously carried by friction) was added to the 16 tons already on the toe, the safe bearing value of the hard crust was reached, and the structure began to settle into the softer material beneath it, shown in "black" on the plan. Whether the piles punched through the crust, or whether piles and crust sank together, cannot be ascertained.

As the "mud pocket" was there, it was unfortunate that it did not extend equally under the whole pier; for in that case the piles might have gone down vertically and preserved the horizontal line of the pier. Judging from the condition of the brick arches just before the fall, and from the fact that the rubble haunching was carried up almost to the line of the crown of the arches, the pier might, under this condition of affairs, have sunk much lower than it really did before destroying the

stability of the arches. As it was, one end of the pier sank and the other practically stood firm. Owing to the stiffness of the platform under it, the arch pier and foundation masonry did not crack vertically, as would have been the case with a weak platform under these conditions. But the platform and pier on it remained intact, one end of the mass merely settling lower than the other. As the piles were fastened to this platform, the effect was to throw out of the perpendicular all those piles that were on hard bottom, pushing their heads toward the south. As the upper strata of the soil at that point were soft and afforded little lateral resistance, it was only a question of time when the angle made between the platform and a horizontal line should become sufficiently great to overthrow the piles.

An examination of Pier No. 2, after the fall, showed that it had settled into the soft surface material almost vertically—the springing line being about 12 feet at the north and 6 feet at the south, below its normal position ; thus proving that it had overthrown the piles and settled down upon them. The pier was still unbroken, but had pushed several feet to the southward. The spandrel walls had fallen vertically, and the north spandrel, with the skewback and a considerable portion of the ringstone and brick arches still attached to it, extended out some distance over the pier.

In closing this article, the following comments may not be out of place :

The wisdom of adopting segmental stone arches over such an unstable soil, instead of iron plate girders, has been questioned. But this was a question of foundation, and not of superstructure. Stone arches have been standing on pile foundations for centuries without failing, and it was supposed that it could be done again ; that the destruction would have been less in this case, had iron girders been used, no one will deny.

But stone arches having been adopted over treacherous ground, nothing but the most searching examination into the nature of the underlying material, at any cost, should have satisfied the engineers. Economy in sinking "test wells" too far apart might in this case have been as fatal as depending entirely upon "sounding with an iron rod."

Pier No. 2 should not have been allowed to settle for nearly a year, and to the extent of twenty inches, before some examination was made into the material beneath.

Precautions should have been taken to secure against accident that portion of the work still uninjured. Twenty-four hours hard work

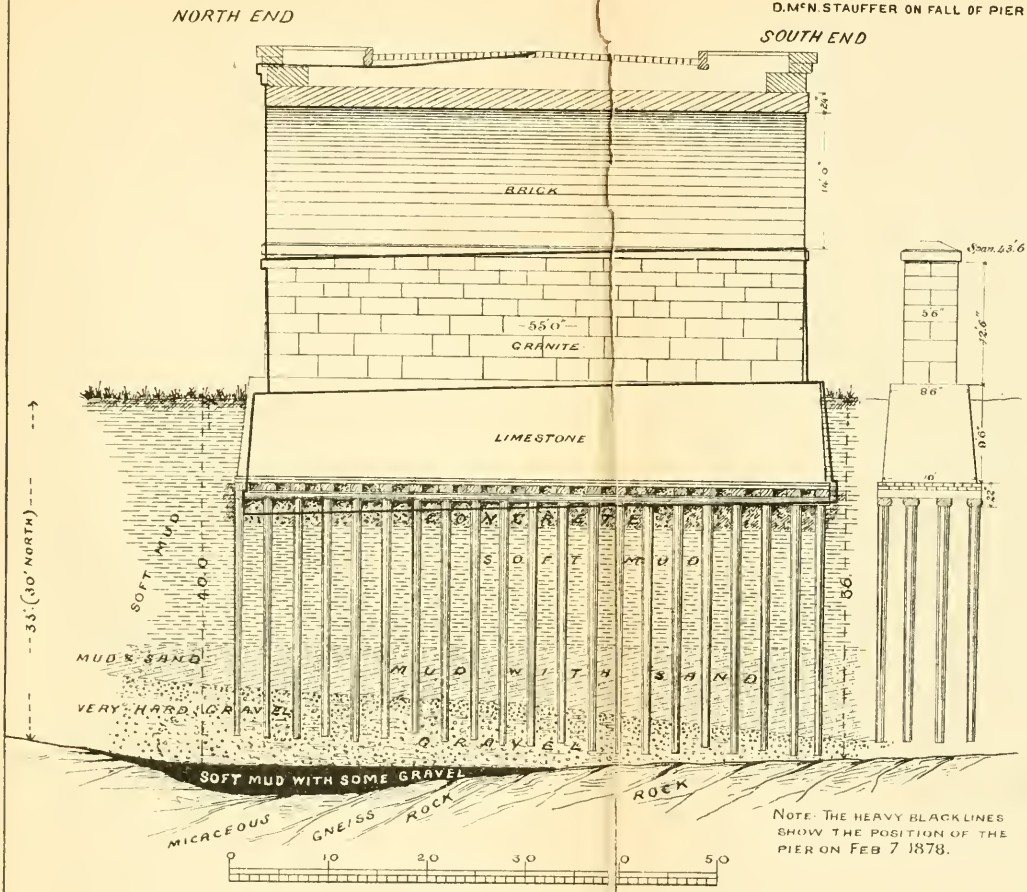
would have done this. This neglect alone cost eighty per cent. nearly, or about $120,000 of the total loss.

In the opinion of the writer, it was very unwise, to say the least, to *commence* repairs by disturbing the material overlying the sinking end of Pier No. 2. Under the form this material had assumed, it was acting as an inverted arch, and its tendency was to relieve the failing pier of some portion of the superincumbent weight. The sudden and rapid increase in the rate of settlement after this material was disturbed, as shown in the letter quoted, seems to bear out this theory. Repairs were commenced just twenty-four hours before the fall of the arches, and at the point mentioned; and in the latter half of that twenty-four hours ("the afternoon" of Saturday, in fact,) the pier sank at least as much as it had in the preceding ten or twelve days.

While the writer assumes all the responsibility belonging to him, as engineer in charge of the original structure, he prefers having it distinctly understood that he has had nothing whatever to do with the bridge since its completion in February, 1876. Since that time the work has been in other hands.

General Description of the South Street Bridge.

This bridge crosses the River Schuylkill, in the City of Philadelphia. The centre line of bridge commences at the intersection of Chippewa and South street, on the east bank of the river, and making an angle of 35 degrees at the east bank, crosses the river—marshy land beyond and two railroad lines—to the intersection of Thirty-second and Pine streets, on the west bank, a total distance of 1 976 feet, with a width of 55 feet at all points except the draw span, which is 36 feet wide. The eastern approach is made up of 380 feet of heavy sandstone ashlar retaining walls, three "flue" arches at the angle, and a granite abutment at the river 45 feet long by 60 feet wide. The river is crossed by two iron-fixed through spans, each 195 feet 8 inches long, and 36 feet between trusses, and a draw span 198 feet 2 inches long and 23 feet between trusses. The river piers are iron cylinders filled with masonry, and sunk to the bed rock by the "Plenum pneumatic process." The piers for the fixed spans are two cylinders 8 feet in diameter, 36 feet apart from centres, with cast-iron ice-breakers, filled with concrete. The eastern pier is bolted to the rock, 32 feet below high tide; the western pier, 46 feet below high tide.



NOTE: THE HEAVY BLACK LINES SHOW THE POSITION OF THE PIER ON FEB 7 1878.

PIER NO: 2 SOUTH ST. BRIDGE

PHILADELPHIA PENN'A:

The draw is carried by nine cylinders, a central one, 6 feet in diameter, and eight others arranged in a circle, each 4 feet in diameter, all tied together by iron beams and sway-braces, and protected by a surrounding cribwork of wood filled with stone. The western arched approach is fully described in the preceding account of the wreck. The railroads are crossed by three iron spans, of a total length of 245 feet. A granite abutment and 75 feet of granite retain wall completes the structure.

The only pile foundations used are under seven of the arch piers and the main abutment west of the river. All other foundations are on platforms of timber resting on gravel.

Note.—The South Street Bridge was authorized by act of Pennsylvania Legislature, finally approved May 3, 1869. By this act a Commission of twenty-two men was created to supervise and control the work, the Chief Engineer and Surveyor of the City of Philadelphia to direct the building of the bridge. On March 1, 1870, the contract for erecting the bridge was awarded to John W. Murphy, C. E.—Moses A. Dropsie, Esq., being the President of the Commission, and Strickland Kneass, C. E., being Chief Engineer and Surveyor of the City. Competitive plans had been previously advertised for, and the plan submitted by J. W. Murphy was adopted by the Commission. The contract price was a round sum of $777,800 for the completion of the bridge. A supplemental contract with Mr. Murphy for the "Draw Fender" raised this sum to $842,800. Work was commenced March 16, 1870. August 12, 1870, D. McN. Stauffer was appointed Engineer in charge for the Commission. In March, 1872, Mr. Kneass resigned his office, and Samuel L. Smedley, the present incumbent, was elected by councils, March 14, 1872, to succeed him as Chief Engineer and Surveyor of Philadelphia. In September, 1874, Mr. Murphy, the contractor, died, and the work was completed by his executors.

On November 30, 1875, the bridge was opened to pedestrians, and formally opened to travel on February 17, 1876.

In accordance with the peculiar municipal organization of the City of Philadelphia, the Department of Surveys merely designs and superintends the erection of all bridges. After the bridge is finished the "Department of Highways" takes sole charge of it and is responsible for all damage caused by neglect to report trouble to the Survey Department, and should ask for plans and estimates for such repairs from the Survey Department. It thus seems that the Department of Highways was responsible, at this bridge, for some portion of the delay in making the proper repairs.

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(Vol. VII.—September, 1878.)

DISCUSSIONS.

(*a.*) On Cements, by DON J. WHITTEMORE and F. COLLINGWOOD.

(*b.*) On Nomenclature of Building Stones and Stone Masonry, by J. FOSTER FLAGG, J. J. R. CROES, J. P. DAVIS, F. COLLINGWOOD, J. VEAZIE and E. P. NORTH.

DISCUSSION OF PAPER CLII.—Notes and Experiments on the Use and and Testing of Portland Cement.*

DON J. WHITTEMORE.—To the engineer about to institute a series of experimental tests of cement Mr. Maclay's paper is of preëminent value in directing an observance of conditions often neglected heretofore.

That low temperature arrests in a marked degree the indurating process, as it does chemical action generally, is well known to many practical engineers. When greater care is taken, not only in regard to the kind of water used, relative fineness of cement, and degree of temperature, of which the paper under consideration specially treats, but as regards a uniform method of manipulation and testing, the subject will then, and not till then, be shorn of the many contradictory results reached by different experimenters, and data will accumulate from which

* Vol. VI, page 312, (December, 1877).

to form correct theory, or, rather, remove the subject from the domain of theory into that of fact.

In my own experimental inquiry in relation to cements, extending through several years, I find that nothing satisfactory can be done without first taking every precaution and refinement in measuring, weighing, and manipulating that can be devised in preparing specimens, and that the resulting tests are of little relative value, unless all specimens are exposed to the same temperature. My own observation leads me to the belief that the action of heat and cold upon mortars of American hydraulic cements is more erratic in character than upon Portland.

The few tests I have made with Portland cement corroborate the deductions of Mr. Maclay as to the weight and fineness of the cement in relation to the tensile strength. I have one example, in which I employed the same sieve he uses (2, 500 meshes to the square inch), which I will refer to. But first I desire to say that I have long since discarded the method of weighing the struck bushel, no matter how filled. By weighing one cubic inch of cement, measured in a mould of that size, under a pressure of 32 pounds, and taking the average of six or eight such weighings, I can arrive at a comparative weight that will be correct to within $\frac{5}{10}$ of one per cent. The amount not passing the sieve, in the example I give, was 13 per cent., and the moulded samples were kept in air at a temperature of about 70 degrees, Fahrenheit, for 24 hours, then placed in water of 58 degrees temperature for six days, and tested immediately after removal, with the following results :

American Portland.	Weight of one cubic inch.	Tensile strength per square inch.
Unsifted.....	$440\frac{8}{10}$ grains.	323 lbs.
Sifted.....	$426\frac{6}{10}$ "	298 "
$\frac{1}{2}$ screenings and $\frac{1}{2}$ siftings.....		331 "

The portion rejected by the sieve when moulded clear appeared to be comparatively inert, but on *regrinding same*, so that it all would pass the sieve, it gave a tensile strength of 352 pounds at seven days. I take it that the regrinding simply allows the active particles of matter to come in closer contact, and within range, I may say, of their molecular affinities. In manufacturing Portland cement it is not possible to subject all the matter to a uniform degree of heat. The result is that a portion of the compound is underburned, and in grinding pulverizes

easily, while that portion approaching vitrefaction is harder and more difficult to grind, and from it a large portion of the coarser particles is derived.

Too great a degree of heat in burning Portland appears to free some of the lime from silica and other matter of the compound, in which condition the free lime comports as ordinary lime, causing cracks, swellings, &c.; hence through the desire to manufacture an article that will develop great tensile strength at seven days, by high torrification, the result is often the production of a cement possessing these objectionable qualities.

Opinions differ as to the effect of salt, sewer, and fresh water upon cements. I am inclined to the belief that water which has absorbed the most carbonic acid, without matter in solution deleterious to cement, will always be found the best for immersion, in hastening the indurating process, and I can corroborate this statement by many examples within my own experience. Take the example of sewer water immersion, given in the paper under consideration. This water must have been well saturated with carbonic acid, and the best results were attained by the use of it; at the same time it can readily be seen why dirty or sewer water may be injurious for making the initial mixture; for there is engrafted into the composition, whether there exists affinity or not, all the injurious elements of the contaminated water, while in water of immersion molecular affinity makes the selection demanded.

Water, or vapor of water, appears to be the vehicle that transports carbonic acid to the molecules in cement, and even in Portland, as I have proved in repeated instances, the indurating process is hastened largely, after the first act of hydration, by the absorption of carbonic acid. This is eminently true of many varieties of American hydraulic cements.

Though not strictly applicable to the subject under discussion I will give an example of the effect of carbonization upon one variety of American hydraulic cement.

I placed several briquettes of pure cement in a bath of water vapor constantly saturated with carbonic acid, for a period of 52 days. Similar specimens were made and immersed in fresh water for the same period of time, and then all were broken with average results as follows:

Tensile strength, fresh water samples.....	156	lbs. per square inch.
" " carbonic acid bath samples..	345	" " " "

The tensile strength of cement has become, to quite an extent, the favorite measure of quality. In ordinary use it is subjected to the direct strains of crushing, breaking, and adhesion, and it is my opinion that no system of testing is complete which does not give these values. From my experience, I judge it to be as impossible to determine the resistance of cements to strains of these kinds, from the known tensile strength, as it is to determine the resistance of cast-iron to crushing, from the known tensile strength of wrought-iron. Cements differ as much in ratio of capacity to resist the several strains mentioned as do the several qualities of iron.

For the purpose of securing uniformity in making cement tests, I believe it would be eminently proper for this Society to recommend a code of rules to be observed by experimenters. Specimens can be made much smaller than those usually moulded, and by so doing insure more perfect form and manipulation, with less labor; which will give, in my opinion, more uniform and trustworthy results. Many of my most satisfactory and reliable tests have not required much more than a thimbleful of cement to each specimen. Great pains, however, were taken to have what was used a fair exponent of quality.

Every careful fabricator of mortar has his own personal equation of manipulation. To secure results of a reliable character from which to determine an empirical formula that will approximately express the activity and energy of cement mortars during the period of induration requires the manipulator to have a delicacy and rapidity of touch and the faculty of rapid and careful weighing and measuring not possessed by the ordinary laborer, who is often delegated to perform this part of the work, and to this neglect I attribute a large share of the anomalous results of many experimenters.

In the endeavor to gather data from which to frame such empirical formulæ, I have found it necessary to test samples immediately on their removal from the water, otherwise anomalous results would often occur, such as are shown in Mr. Maclay's Table 14.

Using every precaution in manipulation, exposure and testing, to secure uniformity, the data so gathered warrant me in saying that for at least two years cement mortars never retrograde in tensile strength, but increase approximately in proportion to some root of the age. For a fair quality of Portland, the index of this root is ten (10), and the expression becomes

$$S = A \sqrt[10]{T} \text{ in which formula}$$

S equals the strength at age T, and

A is a factor determined experimentally by dividing the known strength at any age of sample by the tenth root of its age.

I find that many good and bad cements are quite irregular in their rate of induration up to about the 21st day, beyond which time they increase in a ratio that can be approximately formulated; therefore to give a fair judgment of quality, tests at seven days are not always reliable. The value of A in the above formula should be derived from tests made on or after the twenty-first day after fabrication of test samples.

For the purpose of illustrating how close this empirical formula accords with observed tests for the first two years, I extract from the work of John Grant on the strength of cements, page 122, table 18, the following, converting his time of exposure of samples to days, and his strength measure to pounds per square inch.

The last column is deduced from my formula:

$$S = 303. \sqrt[10]{T}.$$

Age in days.	J. Grant's observed strength.	By above formula.
7	363	368
30	416	426
91	469	476
182	523	510
274	542	531
365	547	547
730	589	586

For further evidence of the correctness of this formula I refer to Grant's table 2, Series A, for hand-made samples, to table 19 and to table 21, samples in fresh water, to which the formulas

$342. \sqrt[10]{T}$,

$267. \sqrt[10]{T}$,

$356. \sqrt[10]{T}$, respectively, approximately apply.

Several tests of my own indicate in a marked degree the correctness of the formula given, when applied to Portland cement of a good or fair quality.

I have a record of tests on Phinney's (American) Portland Cement, purporting to have been made by B. Williams, C. E., of Chicago,

who has the reputation of being a careful experimenter, which are as follows :

Age in days.	Observed tensile strength.	By formula $S = 240. \sqrt[10]{T}$.
7	280	291
30	333	337
91	369	377
182	415	404
274	416	421

showing that the formula agrees in this case with observation, within 3 per cent.

The formula does not apply even approximately to the results shown in Mr. Maclay's table, except, perhaps, in the instance of Saylor's cement, the formula for which appears to be $300 \sqrt[8]{T}$.

I quite agree with Mr. Maclay that the anomalous results shown in this table are to some extent caused by allowing the samples to dry in the open air the last day before testing.

I find that some of the poorer qualities of Portland acquire tensile strength proportional to the 7th or 8th root of the age, with a low factor. The very best I have examined increase as the 12th root, with a high factor.

I desire to express the opinion that if the strength value of Portland cement is to be determined only by tensional strength, the sooner the usual seven-day tests are discarded the better, and substitute tests at 20, 40, and 60 days, and then demand that a fair quality shall not indicate a factor, and an index of root 10 per cent. less than is given in the formula.

$$S = 280. \sqrt[10]{T},$$

S representing strength in pounds per square inch, and T age in days.

The expression $S = A \sqrt[x]{T}$ I find to be of very general application, both for representing tensile and compressive strength, not only of Portland but of Roman cements, when once the co-efficient A and index X are experimentally determined.

It follows, therefore, that the probable activity of a cement can be determined, for a unit of time at any period, by the formula

$$\text{Activity} = \frac{S}{T \times X}$$

From tests and appearances of samples from time to time, I think it possible that induration is the result of, at least, three operations; first,

an initial act of hydration, like hardening in water of plaster of Paris, and of some calcined rocks not properly classed among the cement yielding stones, which substances, under the conditions named, perform the act of setting, and acquire an ultimate crushing strength of, perhaps, 200 or 300 lbs. per square inch only; second, formation of silicate and aluminate of lime, as in the case of Portland cement, and silicate and aluminate of lime, and of magnesia, as in the case of Roman cement; third, carbonization, requiring great length of time, probably centuries, for complete results.

Analysis of ancient mortars show that but few have absorbed carbonic acid to the point of complete saturation, and these few are, apparently, as hard as flint.

With some abnormal cements, after the first act of hydration, their further hardening seems to be arrested, in a marked degree, from after a few hours to, occasionally, twelve or fifteen days, after which violent activity commences, a large afflux of "laitance" takes place, and from this time on, up to about two years, the induration proceeds with a regularity and ratio approximately indicated by the formula given.

F. Collingwood.—I wish in this discussion to give the results of some recent experiments on American cements and bricks. These experiments were made at the works of the East River Bridge by Mr. Abbott, one of the assistants, with the intention of conforming, as near as might be, to the ordinary surroundings of temperature, &c.

The only exception to this rule was that he tried to limit the quantity of water to that amount which would produce in each case the best result. This was found to vary with every lot of cement, even from the same maker. That which in one case would make a clean hard briquette, would in another not give any coherence when rammed. The variation seemed to depend as much upon age as anything.

The percentage by weight of water used is given on the diagram, Plate XXXIV. This was just enough to make the mass slightly moist, after which it was rammed in the moulds. Mr. Abbott estimates that about one-half more water would in each case give a mortar of the right consistency for use.

The fineness of the cements is also noted on the diagram, and indicates the percentage which passed through a sieve of 2 500 meshes per square inch.

CEMENT TESTS
EAST RIVER BRIDGE.

PLATE XXXIV.
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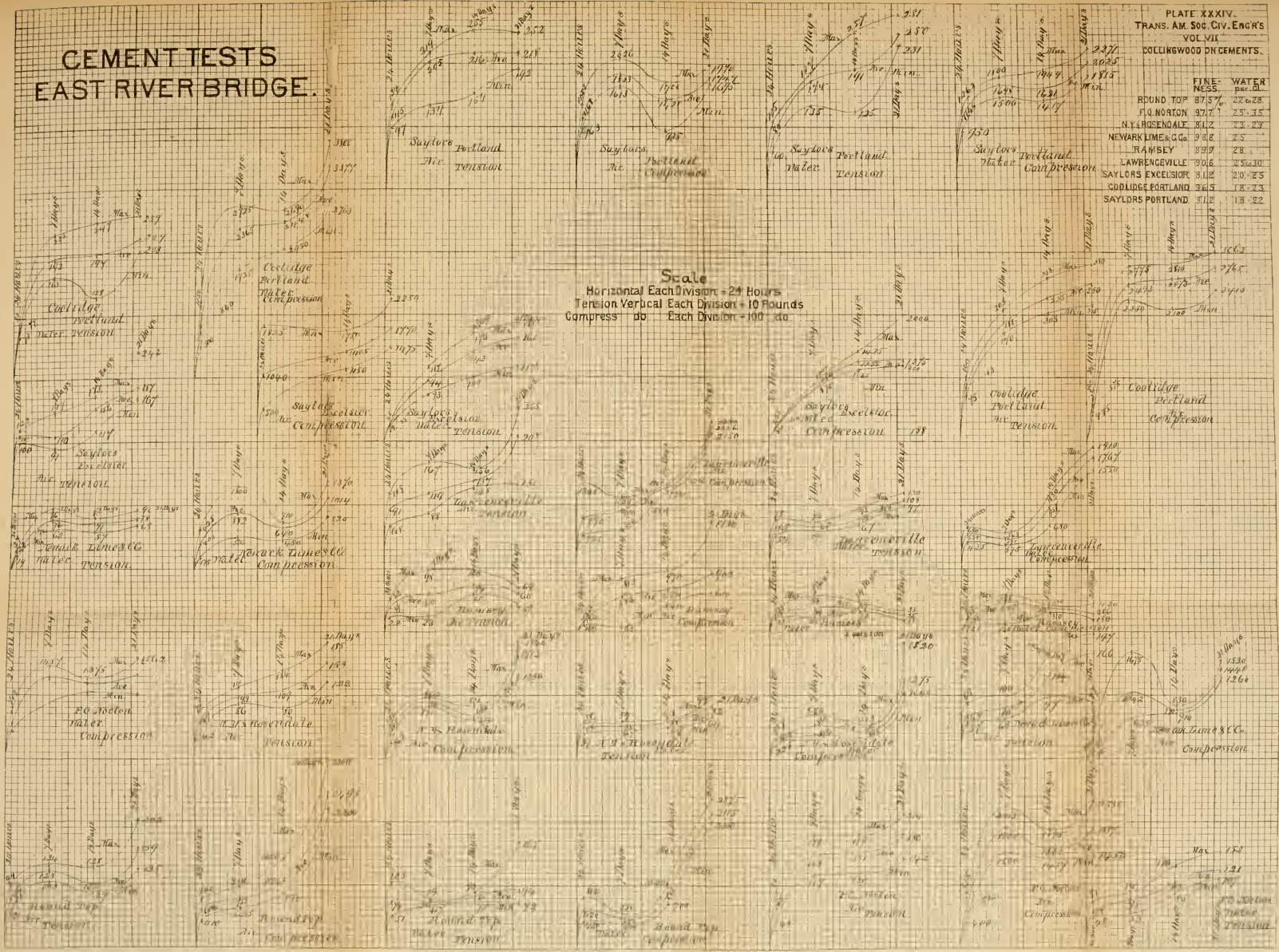
COLLINGWOOD ON CEMENTS.

	FINENESS.	WATER per ct.
ROUND TOP	87.5%	22 to 28
F.O. NORTON	97.7	25 . 35
N.Y. ROSENDALE	81.2	23 . 29
NEWARK LIME & C.Co.	98.8	25
RAMSEY	89.9	28
LAWRENCEVILLE	90.6	25 to 30
SAYLORS EXCELSIOR	81.2	20 . 25
COOLIDGE PORTLAND	96.5	18 . 23
SAYLORS PORTLAND	81.2	18 . 22

Scale
Horizontal Each Division = 24 Hours
Tension Vertical Each Division = 10 Pounds
Compression do. Each Division = 100 do.



The temperature of the air was from 40° to 70°, and of the water used 50° to 60° Fah.

The briquettes were made 2″ × 1½″ in the breaking section, with ends enlarged to fit the clamps in the testing machine. In *compression* a portion of the *same* specimen was crushed, so that the diagram gives the means of a direct comparison between these strains. The size was 2″ × 2″ × 1½″ thick.

Each set of curves represents the results of 40 individual tests, 10 being broken at 24 hours, 10 at 7 days, 10 at 14 days, and 10 at 21 days setting, the briquettes in each set being made at the same time, and from the same barrel.

The lower line gives the minimum strength of the set, the middle line the average, and the upper line the maximum.

The results for the "F. O. Norton," and "N. Y. and Rosendale" brands show a fair average of the cements furnished us for use. But *one* barrel of each of the others was experimented upon, so that it would be unfair to draw comparisons.

The chief point of interest in the curves is the rapid increase in strength up to about 7 days time, then the depression in almost all cases up to the 14th day, and then the marked and steady increase. It would be interesting to know whether this is accidental or real. The first period would seem to indicate the close of the formation of hydrates, and the next rise the beginning of the formation of crystals of silicate of lime, &c.

The curves show clearly also that 24-hour tests are no certain criterion as to the ultimate strength of cements. So far as these experiments go, they show also that there is no certain ratio between tensile and compressive strength, or in other words that the ordinary tests are of little value as to determining the true relative merits of different cements.

By my request, some tests were also made of the strength of brick both in compression and tension. The table is given herewith.

The bricks were selected to give a fair average of "good Haverstraw stock brick," not the hardest burned.

No packing was inserted in the machine between the bricks and the compressing surfaces; so that the strength in compression represents the case of imperfect beds, &c., although it was found that it made but little difference.

The test of whole bricks on *end* gave a minimum strength per square inch in 10 tests, of 1 600 lbs., a maximum of 3 060 lbs., and an average of 2 065 lbs.

Ten half-bricks were then broken by compression on the *side*, giving minimum strength per square inch of 2 900 lbs., maximum of 6 400, and average of 4 612 lbs.

Ten half-bricks were then broken on the flat, and to our surprise the figures were minimum, 2 669 lbs.; maximum, 4 153 lbs.; average, 3 371 lbs. The less amount is probably due to imperfect bearing surfaces.

Comparing these figures with those given for cements, we see they are fully equal to the best at the end of 21 days, and they represent a fair average of the bricks received by cargo.

As to *tension*, 12 bricks were carefully cut to fit the cement testing machine, and the bearing packed so as to avoid cross strains. The results were, minimum strength per square inch, 90 lbs.; maximum, 358 lbs.; average, 168½ lbs.

This again is about equal to the best cements (omitting the Portlands), after 21 days setting.

The lesson to be drawn is the old one that brick-work has considerable strength as a beam, and such strength can safely be relied upon where the work is well done.

In cutting off some of our walls, laid in cement mortar, which had been laid up from four to eight weeks, the adhesion was such that bricks would break in two in every case. This would not be true with partly filled joints, but is invariably true with good work.

Experiments on the Strength of Bricks.

Compression.

Position.	Load per □".	Position.	Load per □
Whole brick on end ...	1 600	Half bricks on flat side..	3 461
	2 031		3 146
	1 956		3 800
	2 285		3 331
	2 412		4 153
	1 524		2 707
	1 832		2 669
	2 019		3 923
	1 931		3 423
	3 060		3 101
10	20 650	10	33 714
Average.	2 065	Average.	3 371.4

Tension.

		Brick pulled apart.....	122
			100
½ bricks on small side...	5 080		358
	6 400		124
	5 400		144
	5 620		106
	2 900		204
	4 320		124
	4 540		337
	3 780		204
	4 360		90
	3 720		108
10	46 120	12	2 021
Average.	4 612	Average.	168½

Discussion of Paper No. CLI.*—Nomenclature of Building Stones and of Stone Masonry.

J. Foster Flagg.—I consented to take part in the discussion of the valuable paper upon the "Nomenclature of Building Stones and Stone Masonry," without duly considering, perhaps, how little of merit I could contribute to it,—especially with the little time latterly at my disposal.

The subject is quite an important one to us all, as there is scarcely any branch of our profession that does not involve in its practice the construction of masonry. Like many others, I have frequently been at a loss to know exactly the character and class of masonry in the descriptions and specifications of different works from the variety of meaning attached in different localities to the same technical term, or the different terms used to describe very similar kinds of work; and it is very desirable, to say the least, that a uniformity of practice should be determined upon, so that the same term will always convey the same meaning to all, whether in discussions and papers, or advertisements and specifications.

This naturally does not diminish the desirability in all works of importance, of the use of sample blocks, in order that contractors may clearly understand the degree of finish demanded in stone cutting, and that disagreements and contests upon this point during the progress of the work may be avoided.

I notice that the master car builders of our railroad corporations have experienced the same trouble in the confusion of names applied in different sections of the country to the several parts of a car or coach, and that they have taken a step in the right direction, in the compilation of a dictionary of technical terms used in car building, showing all the different significations attached to the same term, and the various terms used for the same part. If they can follow up this work by the simplification of their nomenclature, it will contribute much to the clearness of discussions in their conventions, and to the general understanding of their papers and reports.

A similar dictionary of terms used in all branches of American engineering practice would be of exceeding value, if some one could be found with sufficient courage to undertake its compilation, and to do it thoroughly.

* Vol. VI, page 297 (November, 1877).

In this paper the description of tools used in stone cutting impressed me as being very clear and complete. The section upon stone cutting is also very good, and, perhaps, sufficiently classified for engineering purposes; but, under the head of masonry, it seems to me that something more is needed—that the classification is too general.

As an example, certain masonry on Western Railroads is sometimes classed—very indefinitely—as *box* masonry, from its being used in box culverts. This very frequently means simply rubble work, but it often, with the soft sandstone used in certain sections, becomes almost the "squared stone" masonry of this paper—being sometimes even laid in regular courses—and yet it can hardly be fitly classed thus; the stone is very soft, easily split, and quickly dressed roughly with the face hammer; so the blocks merely roughly knocked into shape with the hammer, are far from being rubble, and yet are much inferior to the "square stone" described (p. 300), under the head of stone cutting, they having no joints that can properly be spoken of as dressed. The character of the work may be better appreciated by the statement that it cost, a few years since, at least 30 per cent. less than abutment masonry with rubble backing, the facing of which in the East would be considered only ordinarily good quarry faced squared stone masonry, with no pitch facing or drafting, except on the angles of the abutments. I give this only as one example.

It is much easier to criticize than to originate, and I confess that I have no substitute to offer at present for this classification—it needing much more study than I have been able to give the subject. I only suggest, therefore, that a little more elaboration in the classification would be desirable.

J. J. R. Croes.—The advisability of making a finer subdivision of classes of masonry was discussed by the Committee. It was found that it would lead to the enumeration of so great a variety of styles of cutting and laying stones, that confusion rather than preciseness would result.

It is believed that the three main classes of masonry suggested, will be found to cover almost every kind of work used in engineering structures, with the aid of some intelligence and a definite idea of what is wanted, on the part of the person who prepares the specifications.

While on this subject, I would like to ask the members present what each understands by the word "build" as applied to cut stones. I have always understood it to mean the *top bed*, but have recently found that

some engineers understand it to mean the vertical end joint. What is the generally accepted meaning of the term ?

A MEMBER.—It is the upper surface of the stone.

J. P. DAVIS.—I believe that in the New England States it is understood to be the top surface.

F. COLLINGWOOD.—I think that by some it is understood to mean the vertical joint. I am in doubt myself which is correct.

J. VEAZIE.—In specifications for cut stone work on fortifications the word *build* means the upper surface of the stone.

E. P. NORTH.—I have always understood the build to mean the amount that the course raises the masonry, or the vertical height of the stone.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

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TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CLXXII.

(Vol. VII.—October, 1878.)

THE USE OF COMPRESSED AIR IN TUBULAR FOUNDATIONS AND ITS APPLICATION AT SOUTH STREET BRIDGE,

PHILADELPHIA, PA.

By D. McN. STAUFFER, C. E., Member of the Society.

Although a paper with this same title, has already been published in Vol. 64, *Journal of the Franklin Institute*—1872—it was written some years before the completion of the structure, and the author hopes that the addition of much new data and the correction of some errors in the original, will be regarded as a sufficient warrant for the entire rehandling of the subject.

American engineering literature is as yet sadly deficient in detailed descriptions of the methods adopted in the United States in sinking iron

cylinder foundations, by the "Plenum Pneumatic" or compressed air process. Such foundations have been used in different parts of the country, and the "Official Reports" of their Chief Engineers exist. But, with few exceptions, these documents deal too much in generalities, and the seemingly unimportant data—the smaller details, which are not touched upon—nearly always prove to be just what the practising engineer wants to know. The writer speaks feelingly, and if the present paper seems tedious or unnecessarily long, his apology is, that he has attempted to make it as full and detailed a description of this one work as is possible with the data now at hand.

For financial reasons the Commissioners under whose supervision the bridge at South street was built, adopted, in 1869, a plan presented by John W. Murphy, C. E., afterwards the contractor for building the bridge. In this plan Mr. Murphy proposed to use for the river piers, cast-iron cylinders, sunk to the rock by the use of compressed air. Compared with the other plans and estimates submitted, his method certainly had economy to recommend it. The river crossing was not a favorable one for cheap and easy work; towards the west bank the rock lay 52 feet below high tide, with a loose material over it, liable to scour to an unknown depth during a freshet. The great irregularity and undulating character of the rock surface—dipping sometimes twelve feet in thirty, was another patent reason for adopting some other style of foundation than those ordinarily in use.

The Site of the Bridge.—The Schuylkill river, where the bridge crosses it, is 467 feet wide from bank to bank at low tide mark, with an average depth of water at low tide of 20 feet, and a range of tide of $7\frac{6}{10}$ feet. To the west of the river was a low marshy meadow, extending some 500 feet inland, and subject to overflow at high tides.

The rock upon which the cylinders were to be founded was a micaceous gneiss, dipping to the northwest, and as mentioned above was very irregular in surface, and generally soft and shelly on top. Above the rock was a deposit of, first, hard gravel, then sand and stiff mud, and then mud; the lower strata intermingled with boulders and some drift-wood. This deposit varied in depth at the pier sites from 24 feet to 5 feet.

The river was crossed by a bridge of three iron through spans; two of them, each 192 feet long, and and 36 feet wide between truss-centres, were fixed, and between these two, was a draw span 200 feet

long and 23 feet wide between truss centres. This arrangement required three piers, one of them a pivot pier, in the river, the centre of the pivot pier being 99 feet distant from the centres of the piers east and west of it, measured on the centre line of the bridge. The footways were outside of the trusses, and made the extreme width of the bridge 55 feet on the fixed spans, and 36 feet on the draw span. The distance from the top of the bridge floor to low tide mark was 42 feet.

The Pier Cylinders.—The piers were made up of 13 cast-iron cylinders, extending from the rock to the superstructure of the bridge, arranged as follows; two iron cylinders, each eight feet in diameter, located 36 feet apart between centres, on a line at right angles to the centre line of the bridge, formed a support for the river end of each fixed span, and for the end of the draw, when closed. The pivot pier was composed of a central column six feet in diameter, and eight columns, each four feet in diameter, surrounding it; their centres located on the angles of an octagon. The outside diameter of the pivot cluster was 36 feet, the centre of each four-foot column being 16 feet from the centres of the six-foot column.

The material in the cylinders was originally a cold-blast charcoal iron—government cannon having been used by the founders in casting them. They were made in sections ten feet long, with a uniform thickness of metal of one and one-half inches. These sections were united by inside flanges 2¾ inches wide, and 1½ inches thick, pierced for 1¼ inch bolts, with the bolt-holes spaced 5 inches apart from centre to centre. The abutting portions of the cylinder sections were carefully faced upon a lathe, leaving a space of one-eighth inch between the *flanges* only, for packing. On the section forming the bottom of a cylinder, as sunk, the lower flange was omitted, to facilitate the penetration of the soil; but to retain the full value of the metal as a bearing upon the rock, this bottom edge was left square, and not beveled as is sometimes the practice.

The average weight of each 10-foot section was for the different diameters as follows:

A section,	8	feet in	outside	diameter,	10	feet	long,	weighed	14,462	lbs,
"	6	"	"	"	"	"	"	"	10,847	"
"	4	"	"	"	"	"	"	"	6,810	"

Plant used in Sinking the Cylinders.—Mr. Murphy did not use a fixed platform in sinking the cylinders. His chief reason for rejecting

such a method being the expense of securing a firm foundation on the river bed, especially where the material overlying the rock was not sufficiently thick to hold piles. The arrangement adopted by him was effective and economical, though some trouble in locating and guiding the cylinders during the operations of sinking, might have been avoided by a more steady support.

Two ordinary canal boats, each 100 feet long and 17 feet wide, drawing 4½ feet of water loaded, formed the basis of his apparatus. These two boats were placed parallel to each other and 15 feet apart and secured in this position by timbers. Resting upon these boats, and extending clear across them and the opening between, were two clamps (E. Fig. 7), each clamp made up of three 18×12 inch timbers laid side by side. The distance between the clamps was adjusted to suit the diameter of the cylinder being handled, and to the inside stick of each clamp upright bolster pieces, about 6 feet long, and shaped to fit the outside of the cylinder, were secured by bolts. The clamps were drawn together and made to hug the cylinder placed between them by two heavy iron rods (X, Fig. 7), each 2½ inches in diameter, with nuts and cast-iron washers, at each end of each rod. The rods were spaced 8 feet 6 inches apart, so as to take between them the largest cylinder.

A substantial four-footed derrick (*B*, Fig. 7) 50 feet high, made of 12×12 inch timber, and well braced, rested upon the two boats, with its apex directly over the centre of the opening between them. The feet of this derrick were secured by strong iron straps and bolts to timbers framed into the two boats for that purpose. The hoisting tackle was made of two double 12-inch blocks, with a 4½-inch rope, the power being applied by a capstan on one of the boats, worked by hand.

Four heavy anchors, laid quartering, one from the bow and stern of each boat, were used in bringing the boats into position, and maintaining them there. This was one of the objectionable features in the floating support, the work being carried on in a tidal river, these anchors required constant watching and adjusting of the chain cables, but a little practice soon enabled the workmen, who were all sailors, by the by, to so manipulate them as to always retain the clamps in the proper position.

To furnish the compressed air necessary in the Plenum Process, a single 8-horse power Burleigh Compressor (*O*, Fig. 6), made at Fitchburg, Mass., was located in the hold of one of the canal boats. This machine consists essentially of two single acting air cylinders, 9-inch

diameter and 10 inch stroke each, the plungers working alternately and vertically, drawing in the air through a valve in the piston head, on the downward stroke, and on the upward stroke compressing it, and forcing it into a small reservoir on top of the machine, through a valve lifted by the action of the compressed air itself. To prevent the expansion of the metal in the piston head, by the heat generated in the process, a fine spray of cold water, with a little oil added, was injected upon this piston head at each stroke of the pump.

A four-inch wrought iron pipe (*N*, Fig. 6) led from the chamber in the top of the Compressor to a storage reservoir (*L*, Fig. 6), which in this case was an ordinary cylindrical steam boiler set on end, 22 feet long and 2 feet in diameter, made of ¼-inch plates. The purpose of this storage reservoir was to keep always on hand, at least, one half hour's supply of compressed air, so that in case of any stoppage of the engine, either from accident or from any other reason, the workman inside the cylinder would have ample time in which to escape. The compressed air was conveyed from the reservoir to the working chamber of the column being sunk, by a gum and canvas hose (*T*, Fig. 6) 4½ inches in diameter. Below the deck of the boat, so as always to be under the eye of the engineer, a pressure gauge and safety-valve were attached to the reservoir, and, as with a tide rising and falling $7\frac{6}{10}$ feet, the weight of the water column was constantly changing, this gauge required careful watching on the part of the engineer, to see that the requisite pressure was always maintained inside the cylinder.

Working Gang required.—The laborers employed on the cylinder foundations at South street were all sailors, due to the fact that Mr. John Andersen, the very valuable and intelligent foreman of that portion of the work, was himself a sea-faring man. This selection of men was a happy one, for the operation of handling and sinking these cylinders was sometimes a delicate one, and as a class, no men are more prompt in obeying orders in an emergency, and ready in expedients than sailors.

The men were divided into three gangs, working day and night while a cylinder was being sunk. This arrangement gave each man four hours on duty, and eight hours off. A full working gang to sink a cylinder eight feet in diameter, was made up as follows—the enumeration including the two relief gangs, and the extra engineer and his helper:

One General Superintendant, at.....	$150 00 per month.
Two Engineers, at.....	3 00 per day.
Two Helpers in engine rooms, at.	2 50 " "
Three Inside Foremen, at.....	2 75 " "
Nine Inside Laborers, at.....	2 50 " "
Three Outside Watchmen, at.....	2 25 " "

The basis of pay was eight hours' work to make a day. As seen above, there were only four men at a time actually at work inside the cylinder, and this only in the larger ones; in those only four feet in diameter, two men were all that could work to advantage.

Uniting the Cylinder Sections preparatory to sinking.—The centre line of the cylinder to be located having been marked by permanent points on the shore, the distance from some known point on this shore line to the outside of the cylinder, was measured by a flat steel hoop-skirt wire, under tension; this wire having first been stretched on shore by means of a spring balance, registering 150 pounds, and the required distance carefully measured, and marked upon it by a wrapping of wire. The boats and derrick were then hauled out into the stream and anchored, with the apex of the derrick approximately over the site of the column.

The sections to form the cylinder were next brought out on a barge, and section No. 1, or the bottom section, which, as before mentioned, had no bottom flange, was rolled up on the clamp timbers, and the hoisting tackle attached to it by means of a heavy beam of wood wedged under the upper flange, and secured in position by temporary bolts passing through the flange and the beam. As soon as this section was hauled up into a vertical position, it was lowered halfway down between the clamps, and held tightly around the middle by screwing up the nuts on the clamp rods (*X*, Fig. 7). The tackle was then removed, and section No. 2 lifted in like manner and lowered down upon No 1. These two sections were then bolted together, a packing of lamp wick dipped in a composition of white and red lead being first put in between the two flange faces, in the slight space left for that purpose. Grummets soaked in the same composition were put about the heads and nuts of the 1¼-inch bolts uniting the two sections. These joints, except in one instance mentioned hereafter, proved perfectly air and water tight.

After the bolts were all in place, and with the hoisting fall still attached to section No. 2, as a precautionary measure, the nuts on the clamp-

ing rods were carefully loosened, the hoisting fall being relieved at the same time and the two sections of cylinder allowed to gradually slip down between the clamps until the middle of section 2 occupied the position originally held by section 1. The nuts were then again tightened up, and the friction of the clamps and bolsters alone depended upon to hold the cylinder.

This operation was repeated until the bottom of the section No. 1 was within a short distance of the river bed, but *not* touching it, at low tide. Careful soundings to the bed rock had been previously taken at the site of each column, so it was known just how many sections would be required to reach this rock and still leave the top of the column some distance above high tide. The airlock was on top of the cylinder. and five 10-foot sections were generally bolted together before this lock was put in place.

THE AIRLOCK.—The airlock (*A*, Fig. 1,) could be attached to the top of any number of sections previously bolted together. A cast-iron diaphragm (*R*, Fig. 3,) of the same diameter as the cylinder, and pierced with bolt-holes corresponding to those in the cylinder flange, was put on top of the section last in place, say section No. 5. This formed the floor of the airlock. Cylinder section No. 6 was then hoisted up and lowered upon the diaphragm to form the walls of the lock, and the two sections 5 and 6, and the diaphragm between them, were all bolted together by 1¼-inch bolts passing through the two flanges and the diaphragm. A similar diaphragm placed on top of section No. 6, and bolted to its upper flange, formed the roof of the airlock.

The metal in the body of the diaphragm plate was 1¼ inches thick, but the edge was 1½ inches thick for a space about 1½ inches wide all around its circumference. This raised edge was faced on a lathe. Each diaphragm was provided with a central man hole (*E'*, Fig. 3,) from 20 inches to 30 inches in diameter, varying with the size of the column and with a door (*E*, Fig. 3,) opening downwards; a rubber washer between the door and diaphragm made the joint air-tight. These doors were cast in two pieces united by flanges and bolts, so that they could be taken apart and sent up through the manhole when no longer required, for the bottom diaphragm was always left in the column—and it might be mentioned that the joint between it and the section forming the walls of the airlock was made more secure by a rust joint, made with sal ammoniac and iron turnings pounded fine. Each diaphragm, shown in plan in

Fig. 3, had in it three openings besides the manhole (E',) namely, for the air-supply pipe F, the water-pipe G, and the equalizing-pipe H or I. These pipes were all ordinary wrought iron gas pipes 3 inches in diameter. The air and water pipes passed through stuffing boxes (O, Fig. 1,) in the diaphragms, and had no communication with the inside of the airlock. The two equalizing pipes H and I, were about 4 feet long, and were simply tapped into the floor and roof and shut by valves at the inside ends.

The air-supply pipe F, was connected above and outside the airlock with the 4-inch rubber hose P, leading to the storage reservoir L, with a stop-cock between the pipe and the hose. This pipe opened at the lower end directly into the working chamber or lower five sections of the column, terminating 8 inches below the floor of the airlock.

The water-pipe G, also had a stop-cock J, above and outside the lock, but terminated at that end in a 5-foot length of iron pipe attached to it at right angles, and used to direct the discharge of water. This water-pipe extended down through the airlock, and maintained its diameter of 3 inches to within 10 feet of the bottom edge of the column, but at its lower end it slipped into a pipe 4 inches in diameter, and about 15 feet long, the two pipes being united by a moveable joint of canvas tubing fastened by iron straps and bolts. By this arrangement the pipe could be shortened and hoisted out of the way of the workmen when not wanted, quite an object in a column only four feet in diameter. But when it was necessary to remove the water that would frequently leak in under the ever-varying head, the 4-inch pipe was lowered down into a sump dug for the purpose, and by opening the valve J, at the top, the excess of air-pressure inside the cylinder acting upon the water surface, was made to lift and discharge this water at the top.

One of the advantages of the form of airlock adopted by Mr. Murphy, besides its economy, was that it mattered not whether this lock was above or below the water surface. If the rock could be reached without adding additional sections to those in place when the airlock was put on, the upper diaphram was removed—and used again—or utilized as old metal. But if it was necessary to lengthen the column—as would be the case when there would be a considerable depth of material overlying the rock—then other sections were added directly on top of the upper diaphragm, and the air and water pipes lengthened by additional pipe or by a hose.

In the smaller columns, for convenience in handling the material, the airlock was always 20 feet high, two cylinder sections being used to form the walls, and in these columns the floor of the lock was always below the water surface.

The average weight of the diaphragms was as follows:

Columns	8	feet in	diameter—	Each	diaphragm	weighed	2,800	pounds.
"	6	"	"	"	"	"	1,600	"
"	4	"	"	"	"	"	783	"

Dropping the Cylinder.—Up to this point the cylinder has been supposed to be free to move, being supported entirely by the clamp beams resting upon the two boats. The next operation was to accurately locate and drop the cylinder upon the bottom of the river. For the reasons given before, this was a tedious work; but when the cylinder was brought finally into exact position, the nuts on the clamping rods were all loosened and the column permitted to slip down slowly, settling into the mud as far as its weight would carry it, the clamps, meanwhile, acting as guides. But as soon as the column had found a bearing on the bottom material, the rods were loosened so as to give at least one inch play all around the cylinder, for it must be remembered that the boats and of course the clamps rose and fell with the tide. Objectionable as a moving guide of this nature may seem, thanks to the intelligent care of the foreman, the greatest variation from true position of any column centre was four inches, except in one case where the rock was so steep that the column slipped upon it. The trouble was not in accurately locating the first sinking of the column, but in preventing it from being deflected at the bottom and thrown out of the perpendicular by the boulders and drift-wood encountered in penetrating 20 or more feet of soil.

Application of the Compressed Air.—After being dropped upon the river bottom the water stood, of course, at the same height inside and outside the cylinder, and it was to remove the water from the cylinder that the compressed air was brought into requisition, the engine having been started and the storage reservoir filled while the cylinder was being located.

The door *E*, in the *floor* of the airlock, was next drawn up and secured by the keeper (*Q*, Fig. 1,) thus cutting off communication between the outer air and the working chamber of the cylinder; then by opening the stop-cock *K*, the compressed air was allowed to pass from the storage

reservoir directly into the working chamber (*B*, Fig. 1,) through the air-supply pipe *F*. The compressor was kept steadily at work, and as the pressure increased inside the water was forced out from under the bottom edge of the cylinder until the cylinder was empty. If the bottom edge of the column had penetrated a stiff mud stratum impervious to water this would not be the case, and the pipe *G*, was brought into play, and the water forced out over the top of the column.

Removing the Material.—The material to be removed by the workmen was that amount found inside the column, in quantity depending upon the depth to which the column had sunk into the mud, &c., by its gravity, the amount of settlement being considerably increased by the erosive action of the expelled water in passing out under the bottom edge. Five feet at one operation was about the average distance sunk in the material met with at South street.

The four men, who, in a column six feet in diameter, would constitute the inside working gang, descend into the air-lock by means of a rope ladder suspended from the hinge rod of the upper door. This door was then hauled up and tightly closed by the outside watchman, and as soon as this watchman had given the signal, "all right," the foreman inside slowly opened the valve in the lower equalizing pipe, *I*, and admitted the compressed air into the lock from the working chamber below. With experienced men, three to five minutes, depending on the amount of pressure, was sufficient time to equalize the air-pressure in the air-lock with that existing below; with new men, a longer time, not less than ten minutes was required.

The door, *E*, in the floor of the air-lock could be opened as soon as the pressure was alike on both sides of it, but not before, and two men of the gang then descended to the bottom of the cylinder, by means of another rope ladder fastened to the hinge of the lower door.

Canvas bags (Fig. 5), holding about 1½ cubic feet each, were filled by the excavating gang, and hoisted up and stored inside the air-lock by the two remaining men. A light block and fall, suspended from an eye-bolt tapped into the upper door, was used in hoisting. To provide light inside, candles of a good quality were used. Twenty bags an hour, hoisted into the lock, and amounting to about one cubic yard, was considered very good work in the most favorable material. But the rate of progress was frequently interfered with by drift wood and boulders appearing under the edge of the cylinder, which had to be cut away with

hammer and chisel. From the effect of the sun on the iron columns, combined with the heat of the compressed air itself, less work was done in the same time in summer than in the winter months.

As long as men were at work inside, the compressor was kept constantly going, supplying fresh air and driving out that which was vitiated by the breathing of the workmen, and the smoke of the candles.

After about 3½ hours inside work the excavators ascended into the air-lock, and closed after them and secured the door in the floor of the lock, then, by opening the upper equalizing pipe, *H*, they allowed the surplus pressure in the air-lock to escape outside, and restored the air within to the normal atmospheric pressure. This done, the outside watchman opened the upper door, and the gang consumed the remainder of their four hour shift in hoisting out and emptying the bags of debris stored in the air-lock.

Making a Sink.—If the gang just leaving had cleaned out the cylinder down to its bottom edge a sink, so-called, was made before the relief gang entered.

This was done by cutting off communication between the storage reservoir and the working chamber of the column by closing the valve, (*K*, Fig. 1), and then allowing the compressed air in the chamber, *B*, to escape by opening the lower equalizing pipe, *I*, the door in the roof of the air-lock being also left open.

As the pressure is removed the water rushes into the cylinder under the bottom edge, cutting away and loosening the soil, and the mass of metal in the column, no longer partially sustained by the lifting force which the compressed air exerted, obeys the law of gravitation, and settles a fresh distance into the material beneath it.

This settlement takes place rather suddenly, and, in loose material, amounted to as much as five feet at one time. Sometimes one side of the cylinder would strike a boulder, or other obstruction, and, by a sudden lurch, throw the column out of the perpendicular. This could only have been prevented by long fixed guides. Guys, attached to the anchor chains, were used to right the column in such cases.

Counterbalancing the Upward Pressure.—In a cylinder 7 feet 9 inches inside diameter the diaphragm forming the floor of the air-lock would present a superficial area of 6,792 square inches, and in sinking such a cylinder in water fifty feet deep a pressure of 21½ pounds per square inch in excess of the atmospheric pressure would be required

to expel the water. Such a pressure acting upwards upon the diaphragm would exert a lifting force of more than 146,000 pounds. While the seven sections of an 8-foot column, diaphragms, &c., included, would only weigh 108,000 pounds, leaving 38,000 pounds to represent the lifting tendency of the air pressure. This had to be provided for by a counterbalance weight.

The friction of the material through which the column is sinking amounts to but little, for the air which is constantly being forced out at the bottom rises to the surface along the outside of the cylinder and, besides keeping the soil in a loose condition, practically surrounds the column with a thin film of air.

Two methods of counterweighting the cylinders were used at South street. In the small columns forming the pivot cluster the clamp beams, *E*, were raised from the decks of the boats at high tide and clamped fast around the column, near its top, and entirely clear of the boats. A platform upon these clamps loaded with stone furnished the additional weight required. This method was objectionable, because it made the column top-heavy and deprived it of its guides in sinking, though, as the columns were close together in the pivot group, the last want was met by bracing to those columns already in place.

In the large cylinders a better plan was adopted. A heavy wooden platform was built inside the column, resting upon the bottom flange of the second section, below the air-lock—that is, twenty feet below the floor of the lock. A shaft three feet square, made of 4-inch plank and well braced, extended from this platform to within five feet of the lock floor, and provided a means of access to the bottom of the cylinder. The space between the outside of the shaft and the cylinder was then filled with stone. In this way the counterweight was applied low down, and, consequently, more advantageously. And the stone was afterwards used in the column masonry, the timber being removed.

Securing the Column to the Rock.—Owing to the slight depth of holding ground at some points it was thought best to bolt the columns to the rock and thus increase their stability.

The rock was levelled off to a solid bearing by hammer and chisel—which was slow and tedious work, consuming the greater portion of the time in securing a foundation. Heavy cast iron brackets (*N*, Fig. 4) were then tap-bolted to the inside of the cylinder by four 1¼-inch bolts in each bracket. The holes in the cylinder for these bolts were tapped

and fitted with wooden plugs, before the cylinder was sunk. These brackets were 1¼ inches thick, in metal, and extended entirely around the inner circumference of the column. The number in each column and their average weight was as follows :

Column,	8	feet diam.,	16	brackets,	average	weight	of each	318 lbs.
"	6	"	12	"	"	"	"	208 "
"	4	"	8	"	"	"	"	183 "

Each bracket was secured to the rock by four 1½-inch bolts, 18 inches long, with a nut on top and steel fox wedge at the bottom.

Filling the Columns with Masonry.—The columns were all filled to the top with rubble masonry, laid dry and thoroughly grouted, with hydraulic cement grout, every three feet in depth.

The first ten feet of the masonry was laid under pressure—that height of stonework being generally found sufficient to seal the column against the entrance of water from below. The stone, sand, and cement used in this part of the work were stored in the airlock, except in the large columns, where the stone in the inside counterweight was used for this purpose. The water for mixing the grout—which grout was made, one measure of Rosendale cement to one measure of sand—was pumped into the column, against the air pressure, by attaching a force pump to the outside end of the water pipe, *G*.

As soon as sufficient masonry was in place to effectually seal the column, the pressure was removed ; the air and water pipes and their stuffing-boxes taken out, the doors taken off, and, if there were no cylinder sections above it, the upper diaphragm was also removed. The filling with masonry was then carried on in the open air ; grout, of one measure of Rosendale cement to two measures of sand, being used in this portion of the work.

Accurate levels were now taken on the tops of the cylinders, and finishing segments cast to order to bring them up to the required height.

The condition and quality of the masonry was severely tested by an accident, of which mention will be made further on. It was found to be very good.

Caps and Ice-breakers.—Each cylinder was finished by a cast iron cap, with a flange projecting over the upper edge of the cylinder, but not touching it. The weight of the bridge was thrown entirely upon the masonry ; the upper surface of the stonework being dressed off for that purpose.

As the fixed spans were 36 feet wide between truss centres, and the draw span only 23 feet wide, some provision had to be made for a seat for the draw, when closed. For this purpose, twelve 15-inch I beams, trussed with 1¼-inch rods, were placed upon the caps of the two 8-feet columns; they extended clear across from outside to outside of caps, and were secured to the caps by tap bolts and fastened to each other by 1¼ inch rods and cast iron thimbles. Cast iron shoes, resting on these beams, carried the lower chords of the fixed spans, and on them, too, was placed the draw seat and the track for the travellers. Doric capitals of galvanized iron concealed the ends of the 15-inch beams, and improved the appearance of the tops of the columns.

To tie the two 8-feet columns together, and at the same time to furnish a support for the ice-breakers, a wooden crib, made of 12 in. × 12 in. timber, was built and sunk around them. This crib was 10 feet wide from out to out, and 64 feet in extreme length, extending 10 feet up and down stream, measuring from the outside of the cylinders. It was finished at low tide mark by a platform 12 inches thick; and upon this platform, between the cylinders, were four 2-feet courses of granite ashlar, cut to fit the outside of the cylinders. The ends of the crib were reduced to 2 feet in width at the points, and carried ice-breakers built of vertical cast iron plates, for a height of 8 feet, and for a further height of 6 feet other cast iron plates, twisted to meet the columns. These castings were connected by inside flanges and bolts, and tied together by rods, and the whole structure filled with concrete masonry. A bracing of 12 in. × 12 in. oak, with tie rods on a line with the outside of the columns, extended from one to the other, and rested in brackets cast in the ice-breakers. They were 14 feet above low tide, and were intended to act as a spring fender.

All the 8-feet columns were entirely independent of the cribs and ice-breakers, so that the latter were free to settle and take their own bearing on the river bed.

An octagonal wooden crib was also built and sunk around the pivot cluster of nine columns, with the inside bracing so arranged as to tie them securely together. This crib was finished at low water mark; masonry was unnecessary, as the wooden fender built to protect the open draw, of course, enclosed the pivot columns also. This draw fender was a wooden structure, faced with 3-inch oak plank, supported partly by piles, and, where piles would not hold, on narrow wooden cribs. The

ends of the fender were protected by massive piers of masonry, on wooden cribs.

Three series of 9-inch I beams, 9 feet apart vertically, were used to brace the pivot columns together. These beams were located on the lines intersecting the centres of the nine columns—one set extending radially from the centre column to each of the eight outside columns, and another set connecting the outside columns with each other. They were connected vertically by iron 1¼-inch sway braces, and rested upon cast iron brackets, tap-bolted to the columns. The two lower series of beams were put in place before the columns had received the finishing segments, and the *location* of the beam brackets, under the peculiar condition of affairs, promised to be rather troublesome. The problem was, working from the *outside* of nine high cylinders—the tops being inaccessible—to find the points where a line drawn from centre to centre of any two cylinders would intersect the outside surface. The solution was a simple one; and as it may save a little trouble in a similar case, we give it: Three wooden *T* squares were made, with the head and blade each about 4 feet long; two of these squares had the back of the head dressed out to fit the outside of a circle 4 feet in diameter, and the other square made in like manner to fit a circle 6 feet in diameter; the centre of the blade in each square being in line with the centre of the circle. In locating the radial beams, the 6-feet square was placed against the central column, and one of the 4-feet squares against an outside column, a fine cord fastened to the first square, on its centre line and just touching the column, was passed over to the second square and down through a notch just at the column, and a weight hung to it to keep it taut. By then shifting the two squares until the cord cut the centres of both blades, the points desired were obtained—for a radius of the 6-feet column and a radius of the 4-feet column lay in the same straight line. The two 4-feet squares were used in the same manner in fixing the points for the beams connecting the outside cylinders.

Rate of Progress in Sinking the Cylinders.—The material through which the cylinders were sunk at South street was a sandy mud at top, gradually becoming more compact and tough, with but little sand, as the depth increased, with a stratum of hard gravel 3 feet or 4 feet thick, just before the rock was reached. Large boulders and driftwood were scattered throughout the two lower strata of the deposit.

Taking the central column, 6 feet in diameter, as an example, with 6 feet of sandy mud, 8 feet 3 inches of very stiff mud or clay, and 3 feet of compact gravel—the time consumed—reckoning from the dropping of the cylinder to the completion of the sealing of the column, with 12 feet of masonry in place, was divided as follows :

Sinking the column to the rock and removing 490 cubic feet of material	40 hours.
Putting on clamp, counterweight and loading it with 18 tons of stone	12 "
Leveling off rock for brackets	53 "
Drilling 72 lineal feet of 1½-inch holes in rock and bolting on brackets	54 "
Laying 336 cubic feet masonry under pressure, 12 feet in height	59 "
Total time	218 hours.

The time required to put in the remainder of the masonry is not on record, but it was done very rapidly as compared to that laid under pressure. The time given above includes that lost in shifting gangs, amounting to about 20 minutes in every four hours.

The small 4-feet columns were generally sunk to the rock and emptied of material in 24 hours from time of drop, deposit same as above. Owing to the confined space in which the men had to work the progress was slower than in the larger cylinders. The average time in the eight 4-feet columns, from time of drop to taking off the pressure, with the column sealed, was 200 hours each.

The four 8-feet cylinders required 14, 22, 24, and 30 days of 24 hours each, rating as above. The time varied directly with the amount of material to be handled, and the nature and pitch of the rock bottom. In one of these columns the rock dipped 4 feet in the diameter of the column. It took 160 hours work with hammer and chisel to secure a level bearing all around the bottom edge. All the rock abounded in quartz seams of varying dimensions, using up the chisels very rapidly. The greatest amount of material removed from any one column was 1,400 cubic feet.

Accident to the Pivot Cluster.—The 4-feet columns forming the pivot group were not braced together in any way until the whole number of columns was in place, but depended entirely, for their

stability, upon the bolts through the brackets and the 17 feet of soil in which they stood. This omission was unfortunate, as events proved.

On March 27, 1872, with the tide running out, and a perfect gale of wind blowing down stream, a tow of five heavily-loaded canal boats, equaling in size those described in the plant, was brought down river. Upon attempting to pass the pivot the captain of the tug boat in some way lost control of his tow, and a boat loaded with pig iron struck heavily against first one and then another of the 4-feet cylinders, throwing them out of position. Upon an examination both were found to be broken off, the break in each case being a clean horizontal one, just under the upper flange of the section of cylinder nearest the rock. The bracket bolts were in nowise disturbed. These two columns were repaired by pulling them back to the perpendicular, the stiff mud just at the break serving as a guide to bring them almost exactly where they were before the accident. The masonry was then removed, the pressure being applied again as soon as the water appeared. When the break was exposed it was found that the broken sections, by a little twisting, could be made to fit accurately. Four flanged segments of wrought iron, ¾ inches thick and 20 inches deep, were now put in and bolted to each other, and tap-bolted to the cylinder. These segments extended entirely around the inside of the cylinder. and at the top had a flange 3 inches wide that abutted against the broken flange. Bolts 1¼ inches in diameter united the two cast iron flanges with the wrought iron one, and the patch was completed. The masonry was then replaced as before, and no further trouble ever experienced from the mended columns. The removal of the original masonry, necessitated by this accident, gave us an excellent opportunity of testing its quality. It was found to be very good, the cement very well set, and the fact that it cost the contractor, in labor, nearly one dollar a cubic foot to take it out proves still further the character of the work.

Danger from Fire.—For the purpose of lighting the inside of the cylinder star candles were used, but owing to the amount of soot thrown off, under the increased height of flame, due to the excess of oxygen in the compressed air, never more than two candles were allowed to be burning, inside, at any one time.

Fire had to be especially guarded against in those cylinders where an inside counter-weight was used. The timbers in this structure were kept saturated with water ; for had a fire once started in the wooden

shaft, burning fiercely, as it would in this unnatural atmosphere, there would have been no hope of escape for any men unfortunate enough to be below it.

As an example of what an exceedingly narrow space can be reached by a fire, once started under a pressure of three atmospheres, the following incident is cited: There was a leak somewhere between the flanges uniting two cylinder sections, and in searching for it the foreman passed a candle around the inner circumference of the column. At the faulty point the flame of the candle was drawn in by the escaping air, and almost instantly all of the luting of red lead and lamp wick was burned out entirely around the column, nearly suffocating the workmen with the fumes of the burning paint.

Code of Signals.—It was evidently necessary to have some means of communication between the men inside the cylinder and those outside. As before mentioned, a watchman was constantly on duty on top of the airlock during inside working hours. This man watched for and answered all signals from within, opened and shut the valve J of the water pipe when so ordered by the inside foreman, and saw that all was being done for the safety and comfort of the laborers. A telegraphic system of taps upon the side of the cylinder with a hammer furnished the means of communicating.

The code was a limited one, but answered every purpose. It was as follows:

One tap	signified	"Open water-cock."
Two taps	"	"Close "
Three taps	"	"Attention."
Four taps	"	"We are coming out."
Five taps	"	"Water going down."
Six taps	"	"Water still going down."
Seven taps	"	"Water stops running."
Eight taps	"	"All right."
Four taps, in pairs,	"	"Danger! Come out at once."

As the telephone has already been utilized in submarine works, where a diver is employed, it no doubt would answer equally as well in caisson and tubular foundations, and save the time now wasted by sending messengers outside, and make unnecessary any such crude method as the above.

Effect of Frost upon the Cylinders.—The same mistake was made at South street, as at Harlem Bridge and at Omaha—and in fact nearly every place where iron tubular foundations have been used in the States. No precautions were taken to prevent the cylinder sections from splitting, by the contraction of the metal, from cold, upon the mass of grouted masonry within. At South street, four or five of the sections were cracked, from this cause the first winter, some of the sections splitting horizontally and others vertically. The worst crack was a vertical one, and opened nearly one-fourth of an inch, but it has never increased since, and seems to have done no further harm. It has been recommended, as a means of avoiding this trouble, to line the inside of the cylinder with staves of pine or other soft wood, a little thicker than the flanges are wide. In this case the wood would crush under the strain, and the tension upon the metal be relieved.

Winter interfered but little with the sinking of the cylinders—work inside was, in fact, done with more comfort to the men than under a summer sun. The formation and flow of ice in the river, caused some trouble in bringing material from the shores, but as the ice was constantly broken up by the tide it was an obstacle easily overcome.

The first column was dropped October 4, 1871, and the work pushed forward with scarcely any interruption until August 22, 1872, when the last of the thirteen cylinders was in place.

Load upon the Pier-Columns.—The maximum load upon the stonework, inside the cylinders, is an unusual one for what might be called rubble masonry and is worth noting.

Taking the Pier for the fixed span, and end of draw formed of two 8-feet columns, the maximum load upon it may be divided as follows:

	Lbs.
One-half weight of the fixed span	412,225
One fourth " " draw "	175,542
One-half load on fixed span, at 80 lbs. per square foot	400,000
One-fourth " draw " at 80 lbs. " "	70,000
Total load—maximum	1,057,767

The diameter of each of the columns of masonry upon which this load is thrown, is 7′ 9″—equivalent to an area of $94\frac{34}{100}$ square feet in the two columns—and this area divided into the total load would give 11,224 lbs., or just 5 tons per square foot, on the masonry at the *top* of the column. The longest cylinder is 71 feet 9 inches, taking the masonry at

130 lbs. per cubic foot, the weight of this column of masonry, acting upon the lowermost course, would equal 9,327 lbs., or $4\frac{46}{100}$ tons per square foot, in addition to the weight of the bridge, or in other words, there would be $9\frac{46}{100}$ tons per square foot upon the bottom course of masonry in the cylinder.

With the draw open, the load upon the 6-feet column supporting the pivot is theoretically much greater; this pivot was designated to be centre-bearing, but fortunately, perhaps, this design was a faulty one, a considerable but unknown portion of the load is actually thrown upon the outside wheels, and then transferred to the 4-feet columns.

But supposing the whole load to be carried by the central column, as was intended, the conditions would be as follows:

The total weight of the draw span unloaded is 702,168 lbs., and the area of the masonry column (5 feet 9 inches diam.), is $25\frac{9}{10}$ square feet. This would amount to 27,110 lbs., or 12 tons per square foot upon the top of the masonry. Adding the weight of a column of masonry 64 feet high, the lowermost course of stonework would have to carry in addition to the above $3\frac{7}{10}$ tons per square foot, or a total load of $15\frac{7}{10}$ tons per square foot.

None of the columns have shown the slightest signs of weakness—though the bridge has been heavily loaded. As before remarked, the quality of the cement and the stonework was very good, thanks to a conscientious foreman, for it was impossible for the engineer to watch all of the inside work. The stone used for the masonry was a hard well-bedded limestone.

Effect of the Compressed Air on the Men.—The effect of working under a pressure of two or three atmospheres, has been so ably and thoroughly discussed by Drs. Jammet and Smith, connected with the St. Louis and East River Bridges, that but very few remarks are necessary here upon that subject.

The maximum pressure to which the laborers at South street were exposed, was 31 lbs. in excess of the atmospheric pressure, and that was for short intervals only, when it was necessary to discharge water over the top of one of the deep cylinders, 72 feet in length, through the pipe *G*.

Except in the small cylinders, 4 feet in diameter, sunk in the summer months, the workmen experienced little inconvenience from their duties, after the first day or two of work inside. Three men of dissipated habits

were sent to the hospital for several weeks, suffering from a partial paralysis of the lower limbs, but soon recovered. The hot sun shining on the outside of the small cylinders, added to the heat of the compressed air itself, and the confined space in which the men had to work, made short hours necessary. Some of the men working under these conditions suffered considerably from bleeding at the ears and nostrils.

Material and Cost of Cylinders at South Street.—These cylinders were put in place in 1871–2, and the actual amount of material used in the thirteen cylinders and their caps, was as follows—excluding the ice-breakers—and all bracing :—

No. of Cylinders, and Outside Diameter of Cylinders.	Length.	Weight of Cylinder Sections.	Weight of Diaphragms.	Weight of Brackets.	Weight of Caps.	Weight of all Bolts.	Masonry.
	Feet.	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	Cu. Feet.
4 Cyls., 8 feet. . .	278 ft. 0⅝-in.	390 461	22 757	21 689	21 456	6 872	13 900
1 Cyl., 6 "	64 ft. 0⅞-in.	69 290	3 258	2 791	3 716	957	1 792
8 Cyls., 4 "	507 ft. 6⅛-in.	345 577	12 528	11 712	7 944	5 024	6 344
Totals.....		805 328	38 543	36 192	33 116	12 853	22 036

Or, to recapitulate, with actual cost to Contractor :

913,177 pounds cast iron..... ....@ $0 02$\frac{975}{1000}$ per pound.....		$27,166 07
12,853 " bolts..... @ 0.09¾ "		1,253 16
22,036 cu. ft. masonry (without labor).@ 0.20 per cubic foot.....		4,407 20
Labor of all kinds in sinking and filling 13 columns		16,344 80
Total cost to the Contractor.....		$49,171 23

The amount paid the contractor by the City of Philadelphia for the work covered by the above recapitulation was as follows :

Iron work.....	$49,109 98	
Stone masonry.....	5,510 40	
		$54,620 38
Adding to this amount—		
2 cribs, ice-breakers, and masonry.....	$28,148 00	
Pivot crib, and column bracing	9,000 00	
Fender to Draw—cribs, 2 stone piers, &c.....	47,000 00	
		84,148 00
Total cost to the City of the piers complete, including the Draw Fender, and its stone piers.....		$138 768 38

The following bits of experience, incident to the use of compressed air, though not of themselves important, may yet serve as a caution to those who are for the first time putting in practice the Plenum process :

The first was due to carelessness, and might have been a serious accident—it came about in this way : The superintendent and a single laborer were inside one of the 4-feet cylinders, fitting on the bottom brackets, the laborer was sent outside for some desired tool, leaving the superintendent at the bottom, and on ascending into the air lock, neglected to draw the lower door tightly to its place—he pulled it up and partially fastened it—but left a space, through which the air escaped into the lock from the working chamber, as fast as he let it out of the lock, through the upper equalizing pipe. The result was, that the water rose so rapidly in the small cylinder, that the superintendent was driven up the ladder, but was compelled to stop when he got to the floor of the air-lock, which, it will be remembered, was in these columns some 8 feet or more below the river surface, for from his side he could not open the door, and before he could make the man above understand his signals, and induce him to shut the equalizing valve, the water was up to his shoulders. In this case a want of proper care on the part of a man who was in too much of a hurry to get outside, nearly cost a valuable life.

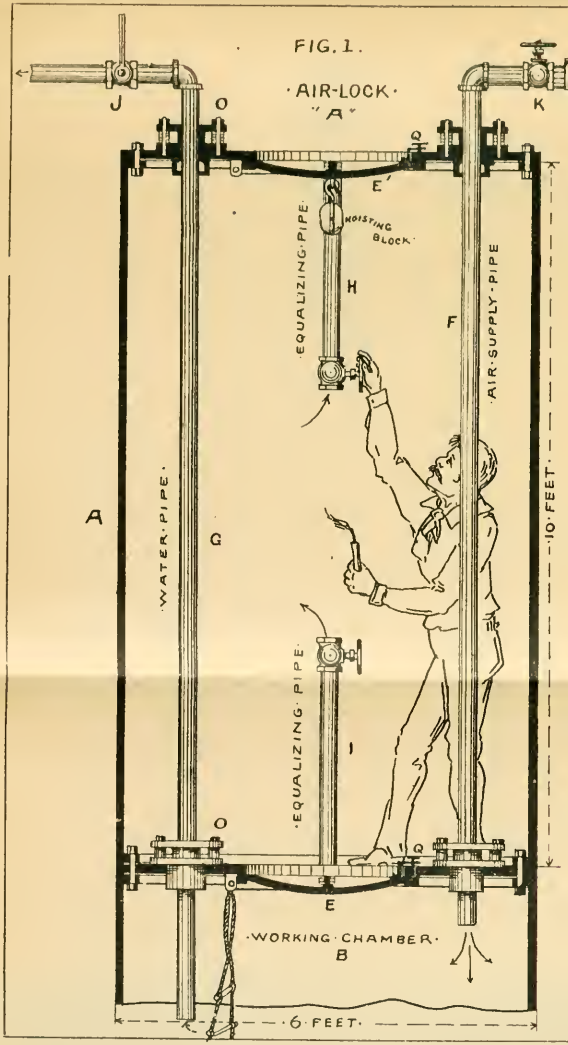
The other incident was one from the combined experience of this same superintendent and the writer, and though, as it turned out, it was rather laughable than serious, it was at the time the subject of very considerable alarm to those interested.

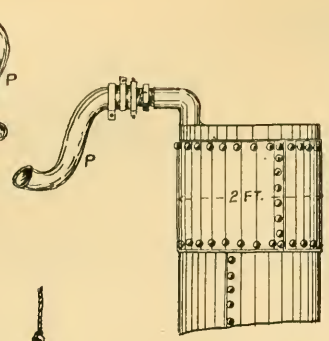
As before mentioned, one of the 8-feet cylinders had struck on a face of rock, pitching 4 feet in 8 feet. There was only about 3 feet of gravel overlying the highest point of the rock, and no mud or sand, and as the water could not be forced lower than the bottom edge of the column in such porous material, bags of clay had been packed under this edge, so as to add in a manner to the length of the cylinder, and enable the laborers to get at and cut away about six inches of the rock. The cylinder was then lowered these six inches, and again packed, and the process repeated until the 4 feet in depth required for a level bearing all around the edge, was obtained.

The writer and the superintendent entered this column alone, for the purpose of making some examination, and just as they stepped upon the rock, they were greeted by a sharp report, and a sudden rush of air,

FIG. 1.

·AIR-LOCK·
"A"





RESERVOIR "L"

FIG. 2.

·BAG·FOR·HOISTING·
·OUT·MATERIAL·
·CONT'S·1½ CU. FEET·

FIG. 5.

·DIAPHRAGM·

FIG. 3.

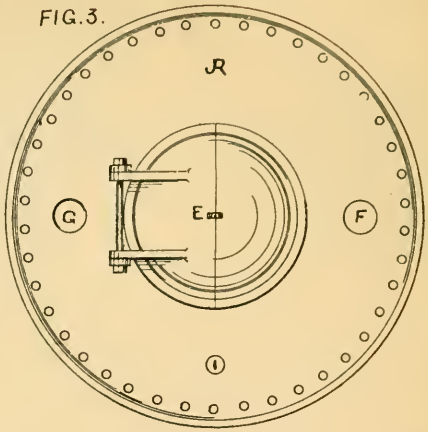
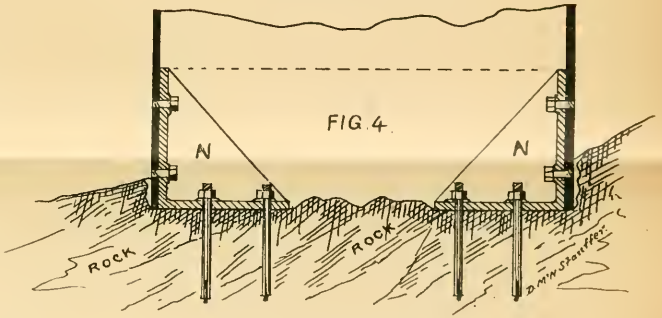
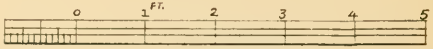


FIG. 4.



·COLUMN·BRACKETS·

·PNEUMATIC·CYLINDERS·
·SOUTH·ST: BRIDGE·
·PHILADELPHIA·PA:



·SCALE·

PLATE XXXV.
TRANS. AM. SOC. CIV. ENG'R'S.
VOL. VII Nº CLXXII.
D. McN. STAUFFER
PNEUMATIC·CYLINDERS.

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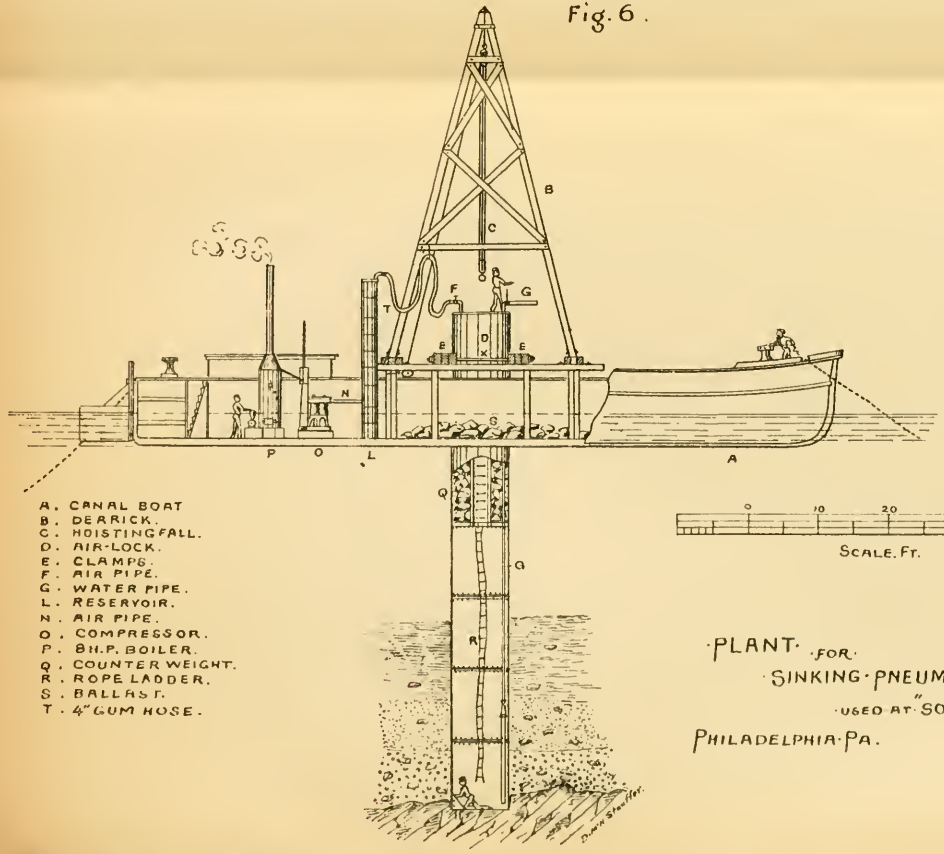
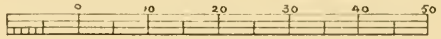
Fig. 6.



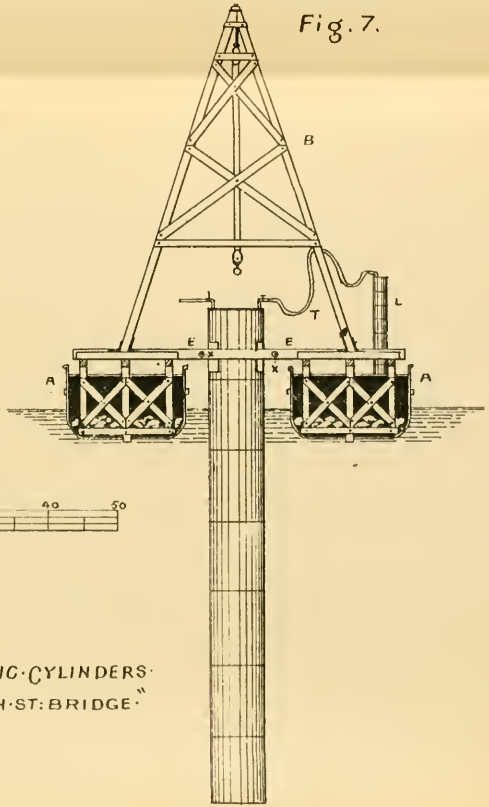
A. CANAL BOAT
B. DERRICK.
C. HOISTING FALL.
D. AIR-LOCK.
E. CLAMPS.
F. AIR PIPE.
G. WATER PIPE.
L. RESERVOIR.
N. AIR PIPE.
O. COMPRESSOR.
P. 8 H.P. BOILER.
Q. COUNTER WEIGHT.
R. ROPE LADDER.
S. BALLAST.
T. 4" GUM HOSE.



SCALE. FT.

·PLANT· ·FOR·
·SINKING·PNEUMATIC·CYLINDERS·
·USED AT "SOUTH·ST: BRIDGE"
PHILADELPHIA·PA.

Fig. 7.



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which put out their candles, followed by what seemed to them a frightful but unaccountable noise. The darkness was almost tangible, boxed up as they were in an iron cylinder, 20 or more feet under water, and the next and most uncomfortable symptom, was a sudden rising of water to their knees, they "stood not upon the order of their going," but went at once—instinctively found the rope ladder—and chance having placed them on opposite sides of it, they made a hasty ascent to the lock, without the least regard for each other's shins or knuckles. Once in the air-lock, they were above the water surface in the river, and had time to breathe, relight their candles, and speculate on the probable cause of this most unexpected demonstration. On going part way down the ladder, 6 or 8 feet of water was found inside, but no cracked cylinder section was visible, as at first apprehended.

The writer and his companion then made their way outside, and found the men there as much excited and alarmed as themselves. They reported that a huge conelike mass of foaming water, 8 or 10 feet high, had suddenly arisen between the boats, and flooded the deck, and to complicate affairs, the engineer, not knowing what was the matter, had stopped the compressor.

An examination was at once entered into, and then it was discovered that all of this excitement was occasioned simply by the blowing out of several of the clay packing bags, at the bottom of the cylinder, the air in its sudden rush out of this opening, put out the candles, and carried with it on its way to the surface, a quantity of small gravel, and raised the cone of water seen by the men above. It was the scratching of the gravel on the outside of the cylinder that made the curious and unaccountable noise mentioned. All very simple and amusing when the true cause was known, and though the same thing happened again, in a lesser degree, it was not accompanied with the same feeling of alarm.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

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NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CLXXIII.

(Vol VII.—October, 1878.)

SUBMARINE TELEPHONING.

By CHAS. WARD RAYMOND, C. E., Junior of the Society.

A means of communication, direct and at the same time easy and reliable, is and has been a great desideratum by those engaged in submarine work. The method of signaling now employed, by jerking upon the life-line, although, perhaps, sufficient for ordinary work, is, at the best, deficient in rapidity and reliability; and where the work is of such a nature, that a word cannot express that which the diver would report to those above, it becomes necessary, in order to facilitate the work, that some other means be adopted.

Several attempts have been made in this direction, but none of them resulted satisfactorily. One may be mentioned which consisted in introducing into the air supply circuit, an air-tight chamber, sufficiently large to admit a person, communication being kept up with the diver through the air-hose, by the assistant in the box, or air-tight chamber.

It has been reserved for the telephone to solve the problem, and by the use of this instrument it has been already accomplished by several engineers, with favorable results.

Experiments were begun by the writer about September 1st, 1878,* to test the practicability and utility of the telephone in the submarine work in connection with the construction of the bulkhead wall, now being built by the Department of Docks of this city.

The instruments used at first were two "Phelp's Duplex" telephones, loaned for the experiments by the Gold and Stock Telegraph Company through the courtesy of Geo. B. Scott, Esq., Supt.

The "Phelps" telephone is peculiarly adapted for this purpose on account of its shape and size. It is oval and flat, 5 inches by 2½ inches, and ⅝ inch in thickness (12.7 x 6.35 x 1.59 c. m.)

One telephone was placed in the diver's helmet, and fastened in such a position, that by simply turning his head the diver could place his mouth or his ear to the instrument. The other telephone was placed on the scow which carried the air-pump and diver's helpers.

The connecting wires were insulated (double covered paraffined office wire, No. 18) and passed through the air-hose.

Beginning at the helmet telephone, the two wires pass from it through a small opening made in the fan-shaped air-distributor in the back of the helmet, the hole being bushed, to prevent wearing the covering of the wires; passing into the hose, and through the hose until they reach the couplings at which connection is made with the upper telephone. This is done as shown in the sketch. Two couplings, separated by about one foot of hose are inserted in the hose, at a convenient distance from the air-pump, in this case about 15 feet. To the inside of each coupling is soldered a copper wire, to which the insulated wires from the helmet are fastened. A binding screw is fastened to the outside of each coupling into which the wires from the upper telephone are inserted, thus completing the circuit.

* The idea was conceived in March, 1878, but opportunity to carry out the experiments was not afforded until September.

This was found to work very well so far as communication from the diver to his helper was concerned; but in the contrary direction it was by no means satisfactory, as it was found necessary by the diver, when he wanted to hear, to stop the escape of air from the helmet into the water, which bubbled so as to interfere with his hearing.

This stopping the escape of air is done by the diver stooping over, thereby allowing the air to fill the diver's dress, and, of course, affords only temporary relief.

To remedy this as far as possible, a cloth tube, about 6 inches in length, and of about the same diameter as the escape valvecap, was fastened by one end over the escape, leaving the other end free. This gave better results, but still not satisfactory.

It was then decided to try an "Edison Carbon Transmitter," which is a form of microphone, and intensifies, or more properly, increases the volume of the sound. This necessitated the addition of an induction coil and one cell of battery; in this case a "Gravity" battery was used; the arrangement of wires and telephones remaining the same.

The action of the carbon transmitter is quite simple, a description of which is given further on, and on the principle already established, that the secondary, or induced current possesses a high degree of intensity, this new arrangement resulted in the perfect success of the experiment. Conversation was carried on with the utmost facility; it was not necessary to give the diver any signal other than a simple "hallo!" It was also found that the diver could talk in the helmet without putting his mouth to the instrument and be heard plainly, and therefore he could continue his work and conversation at the same time.

The battery, induction coil and transmitter were placed on a shelf on the diver's scow, and together occupied no more room than would a Webster's Unabridged Dictionary; the telephone in the helmet occupied but little room, and, of course, was not at all in the way.

The practicability of the telephone for this purpose was thus definitely settled.

These experiments were conducted in depths varying from 0 to 30 feet, without any perceptible variation in effect.

It has been reported to the writer, that at a depth of 50 feet the telephone failed. I do not know what the conditions were, but should any

difficulty be met with at that or at greater depths, it can be easily remedied by using a second transmitter, placing it in the helmet on the opposite side from the telephone, and connecting it with its own battery and induction coil—placed on deck—by two extra wires running through the hose to two extra couplings. These four wires may be small in size, and occupy no more space in the hose than did the two previously used.

I feel safe in asserting that telephones thus arranged, can be used at as great a depth as a diver can work, if not at a greater one.

It may not be out of place here to mention a fact, as curious as it is novel, which was told the writer by Messrs. F. Collingwood and W. H. Paine, Assistant Engineers of the New York and Brooklyn Bridge, that attempts to signal by whistling, with the mouth or fingers, were a decided failure in the caisson when at a depth of about 45 feet. This may possibly be explained on the supposition that under a pressure of $2\frac{1}{10}$ atmospheres, it might be necessary to change the relative position of the fingers and tongue to produce the sound, which practice in the ordinary condition of the atmosphere enables us to produce. And also, that in whistling in a dense medium, a resistance is met with which is not favorable to the production of the sound, but which, when produced, is conducted with greater rapidity, and consequently is heard more distinctly. From this it may safely be concluded that where the diver can speak the telephone will transmit the sound. As to his being able to hear at that depth, there is no doubt.

As regards the utility of the telephone in submarine works, so short a time has elapsed since its introduction into this Department, that no conclusions can be drawn, other than would naturally present themselves to the intelligent mind.

Much of course depends on the nature of the works upon which the diver is employed. In extended general examinations, where the diver has much to report, and where any delay would be inexpedient, its utility would best be appreciated.

Mr. Francis H. Fisher, Assistant Engineer to Mr. Edward S. Philbrick, on the heavy sea wall, in Boston harbor, has kindly furnished me with the results of his employment of the telephone.

He made use finally of but one wire, which was wound spirally around the outside of the air-hose, and both hose and wire then wrapped with canvas to protect the insulated wire from injury. The circuit was

completed by attaching one wire to the helmet, and the other end to a copper plate suspended in the water from the bottom of the scow. A slight objection to this arrangement may be that communication can only be kept up with the diver so long as the helmet is in the water; and that where the wire passes from the outside through the helmet, the opening must be insulated and air-tight; the wire is apt to become loose, and its insulation destroyed. I think the method herein described, of passing the wire through the hose, much the better way. In this case, two wires form the circuit, are entirely out of the way, are protected by the hose itself, and no other insulation than being covered is necessary. The circuit is thus always complete, whether the helmet is under or above water, as frequently happens in shallow water.

Mr. Fisher testifies to the utility of the telephone, in saying, "The necessity of using the telephone arose in providing for a thorough examination of the masonry in the face of the sea wall, below water, in which it was necessary to record the dimensions and positions of the joints around each stone for some courses throughout the wall. The accomplishment of this would have been impracticable, if not impossible, had the diver been obliged to come up to report; but with the telephone it was made in every way successful." Mr. Fisher used a compact form of the Bell Telephone.

From these and other experiments, we believe that submarine operations can be relieved of much expense, both of time and labor, by the use of the telephone. And much submarine work, heretofore considered impracticable, can now be carried on with facility and expedition. In the caisson, and in the mine its value would be great, especially so in the latter, where, should one portion of the mine by an accident be shut off from the rest, communication by the telephone might be preserved.

As the "carbon transmitter" is of recent date, and its function not generally understood, it may not be irrelevant to describe it and its connections in detail. (See Plate XXXVII.)

The transmitter consists of a thin metallic diaphragm (*a*), (such as is used by photographers for tin-types), about 2½ inches (6.35 c. m.) diameter, on the back of which, and in the centre, is fastened a small projection (*b*) of some non-conducting material—glass or agate—which just touches a thin disc of platinum (*c*) about ½-inch (1.27 c. m.) diameter.

This platinum disc is delicately hinged at (*d*) to a metal connection (*d*), with one of the circuit wires (*e*), but insulated from the other wire.

The disc rests upon a button (*f*) of compressed and finely divided carbon, about ½-inch (1.27 c. m.) diameter, and ⅛-inch (0.317 c. m.) thick, which in turn rests upon a metallic connection with the other wire (*g*) of the circuit. The two wires (*e* and *g*) pass from the transmitter, one to the battery, the other to one pole of the primary circuit in an induction coil, the other pole of which is connected with the battery.

The telephones or receivers are on the secondary circuit.

The induction coil consists of two concentric helices of insulated copper wire; the primary or inner coil (*BB*) consists of a stouter and shorter wire than the secondary or outer coil (*CC*), which is made of very long thin insulated wire. A bundle of soft iron wires (*AA*) is placed in the axis of the coils.

The action of the coil is such that a current from the battery traverses the wire of the primary coil inducing in the secondary circuit a current of greatly increased intensity.

The function of the transmitter is to cause fluctuations in the intensity of the primary current, corresponding to the vibrations caused by the voice. This is based upon a remarkable property that carbon possesses of changing its resistance with pressure; and this property varies directly as the pressure.

When the thin metallic diaphragm (*a*) is caused to vibrate by a sound, it presses against the platinum disc (*c*), (which already touches the carbon button), causing it to press harder against and in a corresponding degree to compress the carbon button, thus varying the resistance which in turn influences the intensity of the primary current, causing it to increase or decrease as the diaphragm moves in or out.

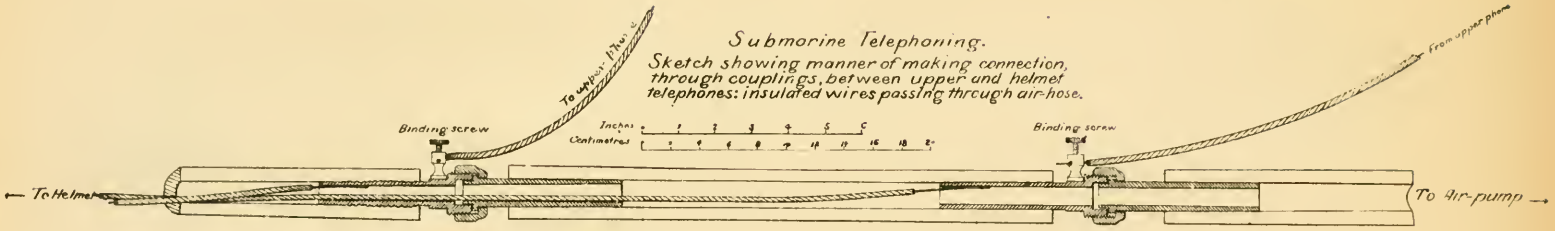
A similar movement of course takes place in the secondary or induced current, which, owing to its magnified intensity, gives an increased effect in the telephones. (*h*) is a screw, which, when removed, exposes the adjusting screw (*i*), by which the carbon button and platinum disc are brought into a proper degree of contact; (*k*) is a hard rubber mouth piece which screws into the metal case (*l*).

NOTE.—In the discussion which followed the reading of the preceding paper on Submarine Telephoning, the statement was made that it would

cost about one hundred dollars to apply a telephone and the apparatus for using it, as described by Mr. Raymond, to the ordinary helmet and appurtenances used by divers in submarine operations.

It was also stated that the work of a diver, with the ordinary means of communication, costs about three dollars per hour while he is at work.

It will be seen that the cost of the telephone and apparatus accompanying it would soon be saved in decreasing the time of employment of diver.



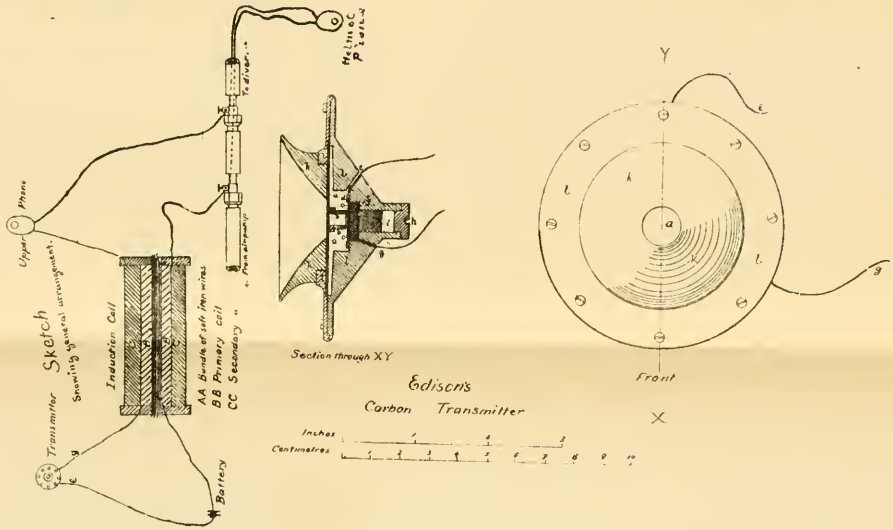


PLATE XXXVII.
TRANS. AM. SOC. CIV. ENG'R'S.
VOL. VII. No. CLXXIII.
RAYMOND ON SUBMARINE
TELEPHONING.

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LE JURY INTERNATIONAL DES RÉCOMPENSES
DÉCERNE
UN DIPLÔME D'HONNEUR
à la
SOCIÉTÉ AMÉRICAINE DES INGENIEURS CIVILS (Etats-Unis)
Groupe VI, Classe 66
LE SENATEUR
COMMISSAIRE-GENERAL
LE MINISTRE
DE L'AGRICULTURE ET DU COMMERCE
PARIS LE 31 OCTOBRE 1878
RF

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

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CLXXIV.

(Vol. VII.—November, December, 1878.)

AMERICAN ENGINEERING,

AS ILLUSTRATED BY THIS SOCIETY AT

THE PARIS EXPOSITION OF 1878.

COMPILED BY

GEORGE S. MORISON EDWARD P. NORTH
JOHN BOGART

A COMMITTEE APPOINTED BY THE SOCIETY TO PREPARE THE EXHIBIT.

Presented with the Report of the Committee at the Annual Meeting, November 6th, 1878, and ordered printed as part of the regular Transactions.

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The Committee appointed by the American Society of Civil Engineers, to prepare an exhibition of American engineering at the Paris Exposition of 1878, has collected the matter contained in the following pages for the use of Members of the Society, and of the profession abroad. In these pages will be found special descriptions of many of the engineering works which have been illustrated at Paris, and also general articles upon different branches of engineering, these articles being intended to show the distinctive features of American practice in the departments which they cover, and at the same time to serve as introductions to the more detailed descriptions which follow, and to render these pages of more permanent value than would belong to a mere descriptive catalogue. For most of these articles the Committee is indebted to other Members of the Society.

The Committee states with regret that many of its requests for models and drawings to be exhibited, as well as for descriptive matter to be embraced in this report, have apparently miscarried, and hence some American works which it was hoped to illustrate were necessarily omitted, and some of the most valuable subjects exhibited are now inadequately described.

REPORT

OF THE INTERNATIONAL JURY OF THE PARIS EXHIBITION OF 1878, ON THE EXHIBIT OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

SOCIÉTÉ AMÉRICAINE DES INGÉNIEURS CIVILS A NEW-YORK.

NATURE DES PRODUITS EXPOSÉS.

Dessins et Photographies des grands ouvrages récemment construits ou en cours de construction aux États-Unis sur les voies de communications.

OBSERVATIONS.

La Société Américaine des Ingénieurs Civils a exposé collectivement les dessins et photographies d'un très grand nombre des ouvrages d'art les plus remarquables exécutés en Amérique dans ces dernières années, ou qui sont en cours d'exécution. Ces ouvrages comprennent des fondations de ponts, suivant divers systèmes, et notamment à l'air comprimé ; des barrages, écluses à plan incliné, ponts tournants, ponts et grands viaducs métalliques, ponts suspendus, dragues à vapeur, etc., etc.

Ces travaux, et particulièrement les viaducs métalliques et ponts suspendus, présentent une étonnante hardiesse de conception, une grande simplicité de forme, une extrême légèreté et une parfaite entente de l'emploi du fer et de la fonte pour atteindre le maximum de résistance avec le minimum de métal utilisé.

Le jury frappé de l'esprit continu d'initiative et de progrès que révèlent les œuvres exposées par la Société Américaine des Ingénieurs Civils, demande qu'il lui soit délivré une récompense exceptionnelle. Il regrette que le caractère de collectivité ne permette pas de décerner à chacun des ingénieurs dont les œuvres sont exposées, les médailles qu'ils méritent.

MEMBRES

DE LA SOUS-COMMISSION DE LA CLASSE '66 (MATÉRIEL ET PROCÉDÉS DU GÈNIE CIVIL, DES TRAVAUX PUBLICS ET DE L'ARCHITECTURE.)

FRANCE.

A. BAILLY, *Architecte, Membre de l'Institut—President.*

FREDÉRIC PONSIN, *Ancient Ingenieur de la Compagnie d'Orleans—Secretaire.*

MOZET, *Entrepreneur des Travaux Publics, et Juge au Tribunal de Commerce de la Seine.*

C. BOUTILLIER, *Ingenieur des Ponts et Chaussées, Professeur a l'école Centrale des Arts et Manufactures.*

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J. A. A. WALDORP, *Ingenieur en Chef des Ponts et Chaussées.*

ESPAGNE,

CARLOS M. DE CASTRO, *President du Comite Consultatif des Ponts et Chaussées et Phares d'Espagne.*

ETATS-UNIS D'AMERIQUE,

WILLIAM WATSON, DR. PHIL., *Membre de l'Academie Americaine des Arts et Sciences.*

[TRANSLATION.]

AMERICAN SOCIETY OF CIVIL ENGINEERS.

NEW YORK.

NATURE OF EXHIBIT.

Designs and Photographs of great works recently constructed, or in course of construction in the United States, upon lines of communication.

OBSERVATIONS.

The American Society of Civil Engineers has exhibited, collectively, designs and photographs of a very large number of the most remarkable works of art, lately executed in America, or which are in course of construction.

These works comprise foundations for bridges of different systems, and notably by that of compressed air; dams, lockages on inclined planes, pivot draw bridges, bridges and great viaducts of metal, suspension bridges, steam dredges, etc., etc.

These works, and in particular the metal viaducts and suspension bridges, present astonishing boldness of conception, great simplicity of form, extreme lightness and thorough understanding of the use of iron and its working to attain a maximum resistance with a minimum of metal utilized.

The jury, impressed by the continued spirit of initiation and progress shown by the works exhibited by the American Society of Civil Engineers, request that an exceptional prize may be awarded. The jury regrets that the collective character of the exhibit prevents the award, to each one of the engineers whose works are represented, of the medals which they merit.

INTRODUCTORY.

The objects of the American Society of Civil Engineers are, the advancement of the science of engineering, the professional improvement of its members, and the cultivation of professional and social intercourse among engineers at home and abroad.

The Society has been organized a little over a quarter of a century; but it remained comparatively dormant until about ten years ago, when it was resuscitated, and started with fresh life and vigor upon a more active course; within that brief period it has achieved a prominent place among American Scientific associations.

The title of the Society would, perhaps, seems to designate it as exclusively devoted to *Civil* Engineering, and while this, in its more common acceptance betokens the calling of many of the members, it is expressly provided by its Constitution that the term shall have its wider significance; in fact among the members are Military, Mining, Mechanical and Gas Engineers; it also has numbers of fellows and associates, who are not specially attached to any of these professions, but who feel an interest in practical scientific pursuits.

The underlying principles which must govern all engineering works and all mechanical arrangements, are the same everywhere; but the climatal, social and commercial differences of countries have led to diverse architectural and engineering structures, adapted to the peculiar characteristics of each country.

Conspicuous among the modern appliances calculated to strengthen human brotherhood, and to benefit the race, are the world's expositions,

wherein are gathered the choicest productions of each country; placed side by side, conveniently arranged for satisfactory examination and comparison. London, Paris, Vienna and Philadelphia, representative cities of great countries, have in turn held these grand World's Fairs, and each succeeding international exposition has brought together, not merely the varied productions of different countries, but also their representative men in the most prominent industrial professions. Different portions of the globe have thus been brought face to face with each other in friendly competition. Especially in engineering, by means of models, photographs and description, much can be seen and learned by those who have not time or opportunity to visit different countries where works have been constructed. At the Philadelphia exposition, European, Canadian and South American engineers, as well as some from more remote parts of the globe, were, through the instrumentality of the American Society of Civil Engineers and the Institution of Mining Engineers, made, at least, partially acquainted with American engineering. These organizations heartily co-operated, and contributed, as far as they were able, to show to their foreign and American visitors some portion of what had been accomplished by American engineers.

Engineering, in most of its modern aspects, is young in the United States.

A country which in a single century has grown from a population of three millions, dwelling in thirteen weak colonies, to a population of forty millions, occupying thirty-eight powerful States, constitutes of itself a novel feature in the world's history; and no careful student can doubt that the rapid settlement and extraordinary growth, physically and intellectually, of the American States is now exerting a wholesome reflex action throughout the civilized world. The people of the United States are the united descendants of almost every European nationality. They have spread over a territory of more than three millions of square miles, embracing almost every variety of climate and production. With two great ocean fronts; with the grandest navigable

rivers and lakes, and the richest and most extensive valleys, on the globe ; a great field was opened for the work of the engineer.

The American growth of engineering partook of the new soil, the new climate and the new circumstances by which it was surrounded. In the early part of its history as a nation, the United States had no engineering school. With only weak credit, and mainly dependent upon the mother countries, it now seems surprising how early the spirit of enterprise in the people led to important works of internal improvement. In 1825, the Erie Canal, of the State of New York, three hundred and sixty miles in length, connecting the great chain of lakes with tide water on the Hudson river, was opened. Some minor canals had previously been completed, and some small improvements had been made in a few rivers and harbors ; but there was no national system. States, and individuals under State acts of incorporation, raised the means and conducted the operations. Two years later, in 1827, the railroad system, then just born in England, was started in the United States ; it has now ramified into every State and into nearly every Territory of the Union, and embraces over ninety thousand miles of commercial railroads.

The inaguration and the energetic prosecution of this vast system of public improvements, over an immense territory, much of it sparsely inhabited, extensive regions being settled only as the railroad track advanced, created a peculiar American railroad engineering profession, adapted to the novel circumstances. The American railroad engineer, of half a century back, with the birth of the railroad system, was obliged to construct his formulæ and his works simultaneously, and, in accordance with his financial basis, which was generally very weak. The American railroad capitalist was a thing unborn, as he had to be an outgrowth of the advancing system. American science was young. The present gigantic railroad system, which has cost four thousand millions of dollars, was not dreamed of. The great rivers, the stupendous mountains, the broad, rolling plains, the grand old forests, and the magnificent valleys, were here, in their pristine majesty, and their

subjugation by man, hitherto deemed to be the work of centuries, was, by the magic of American engineering, accomplished in fifty years.

The early American engineers have nearly all departed from the stage ; but the present world should credit them with having achieved great things with comparatively small means. Their children now occupy the improved fields which their fathers won from rude nature, and the civil engineering of America has changed ; scientific engineering has succeeded to the purely practical, and a single branch may engage the lifetime of a professional engineer.

FOUNDATIONS.

Foundation Work, as practised in America, like most other constructive features of public works, has been subject to limitations and requirements unknown to European countries. In America time is always pressing, distances are magnificent, and investment capital limited and urgent for speedy returns. In earlier days scientifically educated Americans were few, and engineers were largely ignorant of the precedent of foreign practice. Their main reliance was on their "home" experience, and that peculiar faculty of adapting ones self to circumstances, that almost all mechanics in a new country possess in a greater or less degree. Work, to be done at all, had to be done cheaply, expeditiously, for capital could not afford to remain passive, and effectively, to avoid future losses and repairs. Had the fathers of American engineering been men of greater education or scientific culture, they doubtless would have been far less successful in their works, and fewer enterprises would have been undertaken. Strongly self-reliant, those men of the earlier days of American engineering accepted fully the requirements of a new country, and set to work to solve the problems appertaining thereto.

In the matter of foundations, these men availed themselves, almost from the beginning, of the great abundance of cheap timber for their works, and time has proved the wisdom of their course and the excellence of their judgment. In fact the free use of timber may be regarded as the chief difference between American and European methods of founding masonry in deep water, or river crossings. Many of the most important railroad bridges have their piers founded on timber cribs filled in with stone, the timber work being carried up to within a couple of feet of lowest water mark before starting the masonry. On bottoms subject to erosion, a plentiful supply of rip-rap is dumped around the founda-

tion, and replenished from season to season until well solidified. This is the most common system employed throughout Pennsylvania and New York, and in fact in all States where the character of the river bottoms is of such a nature that a solid bearing on rock, hard pan, or gravel, can be insured. Where a soft material overlies a hard bottom, loose stone is thrown in, which soon forms a solid bearing for the crib work, or the crib is built tight with square timbers, with an open bottom, sunk by temporary loading, the soft material—mud, sand, or silt, as the case may be—sucked out by pumps or dredged out, as may best apply to the circumstances, the void then being filled in with concrete or broken stone. In case of a rough or sloping bottom, the lower courses of the crib are made to conform to it as nearly as possible, from previously determined soundings. Many of the cribs used are of round logs, notched at their intersections and secured with long drift bolts. For bottoms ill adapted to crib work, the most usual practice is to drive piles, the area of the foundation having been previously dredged below scour, if possible. The piles are cut off truly level by means of a horizontal saw on a vertical shaft, or the simple device of a pendulum saw, and as close to the bottom as possible. The interstices between the piles are leveled up with stone. On the bottoms so prepared a crib is sunk, economising the masonry up to near low water mark, or a timber caisson is floated over the piles, the bottom of which forms the platform for the masonry, which is carried up in the usual way as in the open air. To control the flotation, a valve is sometimes provided in the caisson, through which water may be admitted to be pumped out again as occasion requires. The sides of the caisson are detachable, and are used again, should there be more than one pier to found. A modification of the former method has been practised by depending on the *piles* for the immediate bearing of the platform, and using a timber crib as a protecting envelope surrounding them, all voids being filled up with stone or concrete. In this case the piles, of course, are cut off at the distance below low water that it is desired to commence the masonry. In all cases where there is any possible chance of scour, it is usual to protect the area surrounding such foundations by means of rip-rap.

Exceptional works often require expensive methods; but even such works, in this country, are of very recent dates. The application of the pneumatic system, so long practised in Europe, to the foundations of the East River and the St. Louis bridges, are examples familiar to the

profession, having been detailed at length in the printed reports of their respective engineers. They are probably the most extended examples of the system extant, and required great boldness and constructive skill to carry out. Two notable improvements were developed in the construction of the St. Louis bridge piers, viz.: the use of the water column for driving out the sand through pipes, and the placing of the air lock at the bottom of the well, leaving the long ascent and descent of the workmen to be accomplished in the ordinary atmosphere. The common European practice of using iron cylinders with the pneumatic system, has been applied in this country to but few bridges, of which that at Omaha is the most extreme example. The Poughkeepsie bridge, now building, has its enormous piers founded on huge square-timbered cribs, sunk by dredging through the wells formed by the cross walls of the cribbing, to a depth of 110 feet and over; the crib work being filled with concrete forms a solid base for the masonry commenced 25 feet below low water, and towering 135 feet into the air above high water mark. This is the boldest example of timber foundation work on record, and perhaps meets the most extreme case of deep water foundation that the engineering needs of the country will ever call for.

Out of the persistent demand for accomplishing results cheaply and rapidly, grew what American engineers know as the Cushing System, which consists of square timber piles driven to their full bearing in intimate contact with each other, forming a solid mass of bearing timber. Surrounding the pile cluster so driven is an envelope of cast or wrought-iron, sunk sufficiently in the mud or silt simply to *protect* the piles, all voids between piles and cylinders being then filled with hydraulic concrete. The piles alone support the load. Several such foundations have been used, and answer an admirable purpose. Time alone will tell whether the only objection that can be used against the system, viz.: "dry-rot" has any foundation in fact.

The water jet has been used economically and with good results for sinking piles in soft bottoms, notably in the case of Tensas bridge in Alabama, where iron cylinders were put down by simply directing through gas-pipe a system of jets driven by an ordinary steam pump.

The preceding description fairly covers the leading features of foundation methods practiced in this country—except, perhaps, coffer-dams of which no mention has been made. As a rule, coffer-dams are

avoided, excepting in comparatively shallow waters, and where there is some reasonable certainty of getting a tight bottom. The uncertainty of what future trouble and expense a coffer-dam will develop before the bottom is laid bare, causes engineers to select some one of the several methods previously outlined. A novel floating coffer-dam has been built in New York, that has been experimentally successful in laying dry a mud bottom, but no work has thus far been laid with it; it is simply a long rectangular double walled caisson with an inside court as it were, having sheet piling sliding in guides in the inner wall of the caisson, which when driven down into the mud or clay (it is only practicable on a homogeneous mud or clay bottom) acts as ordinary sheet piling. The caisson is sunk by filling its walls with water, and is rigged with steam pumps for exposing the bottom, and clearing the caisson of its water ballast. The ends of the caisson are movable, permitting of its removal as a whole from the completed work.

Screw piles, so largely used abroad, have been used but little by American engineers.

Looking to the future, it is not probable that demands will be made upon the skill of American engineers for much more difficult foundation work than has already been accomplished, and it may be many years before projects arise which will match those already executed in this class of constructions. But be that as it may, American foundation work will long be characterized by a free use of timber in the form of cribs, caissons, platforms and piles, and a very limited use of iron, pneumatic processes or coffer-dam work, in which particular as was remarked in the commencement, lies the distinguishing characteristic between American and European systems of foundation.

SUBJECTS EXHIBITED.

1. *Two photographs of masonry bridges on the Lake Shore & Michigan Southern Railway, selected from a lot of photographs sent to the Society by* Mrs. Charles Collins.

2. *Photographs showing the towers of the East River Bridge in process of construction.* W. A. Roebling, Chief Engineer.

The East River Bridge consists of a central suspended span of 1 595′ 6″ length between centres of towers, and two side spans, also suspended, each 930 feet long.

The approaches increase the total length to about one and one-sixth miles.

The ends of the cables are anchored in two masses, containing a total of 26 000 cubic yards of masonry. These masses are each about 119 feet by 132 feet in plan at the base, and about 89 feet high, and are founded on a grillage of timber from 4 to 7 feet thick, which rests directly on sand ; the timber being below the level of water in the soil, and consequently not subject to decay.

The piers at either side of the river rise to a height of 271½ feet above mean high tide. At high water surface the extreme measurements were in plan, 57′×141′ in Brooklyn, 59′×141′ in New York.

In Brooklyn the foundation rests mostly on boulder clay, but a sufficiently uniform foundation was not found until a depth of 44½ feet below tide was reached. To obtain this depth a timber caisson was sunk, having exterior dimensions of 102′×168′, and a height of 24½ feet. Both caissons when launched were 15 feet high, and additional timber to the heights named was put on after launching. The air chamber, which was afterwards filled with concrete, had a height of 9½ feet. The final pressure at bottom of foundation will be about 5½ tons per square foot. The pressure on top of the timber is 9¼ tons per square foot. The total quantity of masonry, including concrete, 43 900 cubic yards.

The New York pier rests on compact sand and gravel, immediately overlying the bed rock. The caisson was 102×172×31½ feet, also of timber. The edge of the caisson is 78 feet below tide. The tower contains about 55 000 yards of masonry and concrete. The pressure at the base is about 6¾ tons, and on top of the timber about 10½ tons per square foot.

Work on the Brooklyn caisson was begun November 1st, 1869. The caisson was launched in March, 1870, and put in place, and the first

stone set June 15th, 1870. It was sunk to full depth and filled in by March, 1871. Stone work of the pier completed December 1st, 1874.

The New York caisson was begun September 6th, 1870; launched May 8th, 1871; put in place and sunk to depth, May 17th, 1872; filled with concrete, July 22, 1872. First stone of pier set, October 31, 1871, and pier finished July 15th, 1876.

Last wire of cable laid, October 5th, 1878.

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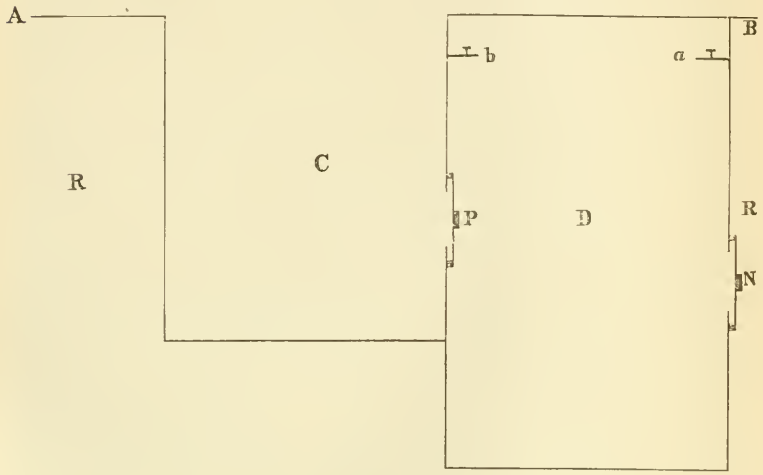
3 *and* 4. *Detail drawing and photograph of the foundation works of the East pier of the St. Louis Bridge.* James B. Eads, Chief Engineer.

All the great piers of this bridge, four in number, stand upon the bed rock of the river. Two of them are nearly two hundred feet high. The base of the West abutment was laid within a coffer-dam; the other three were sunk through the water and river sand by the method of compressed air. The method employed was in many of its features entirely new, and in nearly all important respects the work was on a scale far surpassing all previous experience. The most difficult, on account of the depth and strength of the river and the distance to the rock, was the East pier, and it was undertaken first. The iron caisson enclosing the air chamber was first towed into position between the large guide piles. Its length was 82 feet, its width 60 feet, and the depth of the chamber was 9 feet. The ceiling of the chamber was stiffened by cross plate girders, and the walls by iron knee braces. Two walls of oak timber running the entire length of the caisson helped to support the ceiling as soon as the caisson reached the bottom of the river. These walls, as well as the outer walls of the caisson were built with a broad flat base which took a bearing on the sand.

In all cases the masonry was laid in the open air, beginning on the roof of the caisson. Powerful air pumps supplied air at a pressure sufficient to expel all water from the air chamber. The masonry of the East Pier was protected from the water by a coffer-dam of iron plates riveted to the edges of the caisson, and the descent of the caisson was to a certain extent regulated by suspension bolts and nuts. The iron coffer-dam around the masonry was, with the exception of a few courses required while the caisson was still floating, omitted from the West Pier as a costly and unnecessary feature, while the East Abutment was sunk in the most satisfactory manner, without either the coffer-dam or the suspension rods.

Entrance to the chamber was through air locks, the main one being in the center, as shown in the drawing. The method of entrance and exit is easily seen from the diagram.

A B is a portion of the ceiling of the caisson. *C* is a cylindrical well sunk into the air chamber and open above. *D* is the air lock placed wholly within the air chamber, and connecting by the close fitting door *P* with the well *C*, and by a similar door *N* with the air chamber *R R*.



The door *N* being shut and *P* open, the men descend into the well *C* and step through the opening at *P* into the air lock. One closes the door *P* while another admits the compressed air from the chamber by means of the cock *a*. When the air ceases to enter, the door *N* swings open. Exit is made by reversing the order and allowing the compressed air of the lock to escape at *b*. In the East Pier, ascent to the top of the masonry was by means of stairs. When the caisson was on the rock, the stairway was fully one hundred feet high. The stairs were supplemented in the East Abutment by an elevator, to the great relief of the workmen.

The East Pier was sunk from the surface of the river to the bed rock in 134 days, the East Abutment in 132 days. The sand was removed by sand pumps, the general arrangement of which consisted of a water jet discharging upward through the centre of a hollow globe; this globe was placed in the caisson at the bottom of an iron tube which extended upwards through the masonry and was connected with a flexible tube below; the lower end of the flexible tube was kept submerged in the water below the level of the bottom of the caisson and this water was drawn upwards by the inducing force of the jet, carrying with it a large quan-

tity of sand; the general arrangement was not unlike that of the Giffard injector. The sinking was mainly regulated by undermining the bearings. In the East Abutment, which is probably the most successfully constructed deep foundation ever built, the process of "settling" was reduced to a science. The discharge of the sand pumps was in excess of the masonry, though as much as 346 cubic yards were laid in less than twelve hours on that one pier. Whenever the height of the masonry required that the pier should sink, the air pumps were stopped, and the air was allowed to escape slowly from the chamber. The motion of the water along the outer faces of the masonry and caisson, and under the cutting edges rendered the sand sufficiently mobile to produce a gentle and perfectly regulated descent of the caisson and its huge burden; workmen meanwhile undermining the central walls. The starting of the air pumps would instantly stop the settling.

The caisson of the East Abutment was built of wood, with only a single thickness of iron plates to make it air-tight. The wood consisted of squared oak timbers bonded and strongly bolted. The timber surfaces were whitewashed, and the air chamber was brilliantly lighted by lamps burning in glass globes fed by compressed air, and discharging the products of combustion into the upper air through tubes.

When the bed rock was reached it was cleared of all loose material, and concrete was packed under all the supporting surfaces. The air chambers of the channel piers were filled solid with concrete. This was mixed on the top of the masonry, and introduced through small air locks, and being done at the maximum depth, was a work of great difficulty, involving no small danger to the workmen. The caisson of the East Abutment was filled with sand, except under the walls which rest on concrete. The caisson was allowed to fill with water and the sand was then pumped in, and required no packing except a few inches under the roof, where it was rammed as firmly as possible. The base of the East Abutment is 83 feet by 70 feet 6 inches; the top is 64 feet 3 inches by 47 feet 6 inches. The height of the masonry is 192 feet 9 inches. It contains 22 453 cubic yards of masonry, and its weight, with half the span it supports, is about 46 500 tons. Its base is 134 feet 6 inches below high water.

The caisson of the East Pier cost $111 000; that of the East Abutment, $139 700. The masonry and sinking of the East Pier cost about $469 000; that of the East Abutment $451 000.

Twelve men who worked under the East Pier died from the effects of compressed air. One only died at the East Abutment, and he suffered the penalty of positive disobedience of orders. Excepting this unfortunate loss of life, no serious accident attended the construction of these massive foundations.

5. *Detail Drawing of the foundation work of Pier No. 5 of the St. Charles Bridge over the Missouri River.* C. SHALER SMITH, C. E.

This bridge crosses the Missouri River at a point 17 miles west of St. Louis, and 20 miles above the junction of the Mississippi and Missouri Rivers. Being within the range of the Mississippi backwater, the variation of the water level at this point is over 40 feet, and the flood speed of the current very great, exceeding in fact 9½ miles per hour twice, during the period occupied in the construction of the bridge. In 1869, after the piles had been driven for the breakwater for Pier No. 5, a heavy freshet occurred, which carried away the works at this point, and in doing so, scoured out a large hole at the pier site, which hole was soon filled with the traveling boulders which move along the bed of this river at such times. After the subsidence of the flood, a careful examination showed that the proposed site was occupied by an inverted pyramid of boulders and drift wood, 200 feet long by 70 feet wide at the base and about 22 feet thick at the deepest part. The caisson, which was of iron, double-walled and cellular, had already been arranged for sinking with the water jet and Ead's sand pump, and was altered to suit the new condition of the case, as follows :

An air lock 12 feet high, was placed at the foot of the down-stream shaft, the upper side of the lock being a large door, which swung vertically, was nearly the full section of the shaft, and was counterweighted so that the strength of one man sufficed to raise it into place. The underside of the air lock was seven feet below the top of the air chamber, and the up and down stream sides were provided with large doors 36 inches by 30 inches, placed as close to the floor of the lock as possible. The air was admitted to or from this boulder lock in less than one minute, through an inch and three-quarters pipe, the stop cocks of which were managed by a man within the air chamber and outside the air lock, as this rapidity of alteration of pressure was too great for human life to endure.

This arrangement was found to work admirably. Small iron cars 24 inches by 18 inches by 36 inches were filled with boulders, and run on skids into the lock, the air was let out, the upper door dropped down, and the fall tackle of a large derrick passed down the shaft, was hitched to the car, and the latter was then drawn out, swung around, and its contents emptied on to a barge, where they were broken up into concreted stone, for use in the hearting of the pier. Many of the boulders weighed from 600 to 1 300 pounds each, and were too large for the cars. These were passed on trucks into the boulder lock, and were taken out in slings by the derrick. After 3 feet in depth of boulders had been removed, the sand which had formed the matrix, generally made a layer of about 12 to 16 inches in depth. This was removed by the Eads

sand pumps, the suction pipes of which reached to all parts of the air chamber.

The most economical method of working was found to be as follows: While excavating, the air was kept at a pressure of from 10 to 15 feet (or 4½ to 6½ lbs. per inch) greater than required by the depth at which the men were working. This dried the bed for two feet below the cutting edge. The boulders were excavated until water was reached, and under the bearing beams were replaced by sand, well tamped; the sand layer was then pumped out and the pressure in the air chamber lowered until the pier sank down to the top of the boulders. A marked feature of this foundation was the great friction of the materials after the boulders had commenced caving and packing. In the last 20 feet the pier never moved until a skin friction of 466 lbs. per square foot of immersed surface had been overcome.

Eads sand pumps removed 18 cubic yards of sand per hour each. They were found to work best with a three-inch discharge pipe and 200 lbs. per square inch water pressure. Three Cameron pumps, with 12″×24″ steam, 6″×24″ water cylinders were used to supply two of the sand pumps, and were worked up to their full capacity in so doing.

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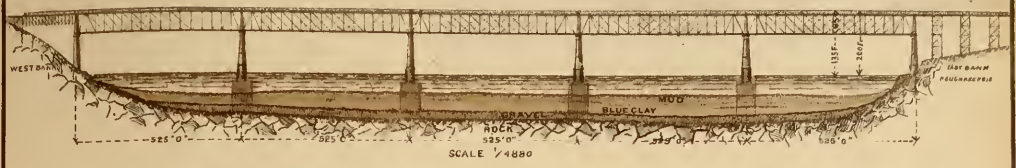
6. *Detail Drawing of the foundation work of the Poughkeepsie Bridge* P. P. Dickinson, Chief Engineer.

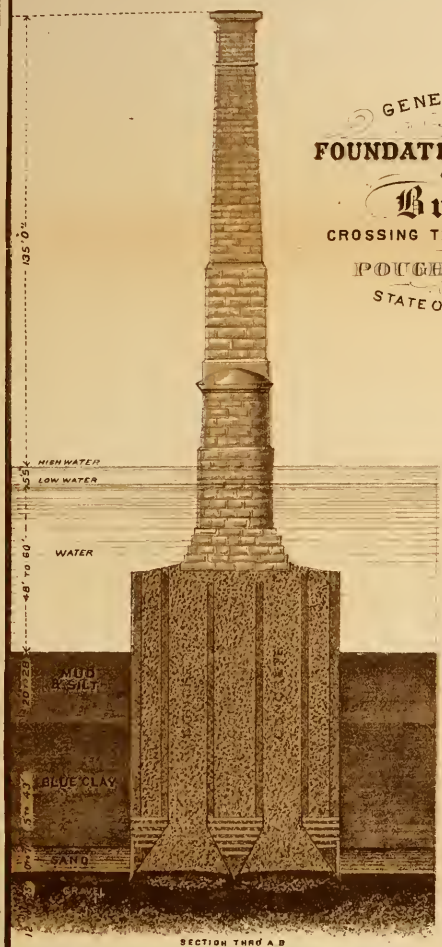
(See Plate XXXIX.)

This work is located at Poughkeepsie, on the Hudson, 75 miles north of New York city. The width of the river at the bridge site is 2 430 feet, and the depth of water from 50 to 60 feet, with a tidal motion of three miles per hour. The bed is composed of 20 feet of sediment and mud, 10 to 40 feet of compact blue clay, 6 to 10 feet of sand, and 10 to 15 feet of coarse gravel, with boulders overlying the rock, which is at a depth of from 119 to 145 feet. There are to be five spans, of 525 feet each, with a depth of truss of 65 feet. The substructure consists of four river and two shore piers, with two abutments, to be built of granite masonry to a height of 135 feet above high tide, having a base of 72 by 32 feet, at 20 feet below high tide, and 40 by 12 feet at top—giving a pressure at the base of about 5 tons to the square foot. The shore piers and abutments have their foundations on rock, on the river bank.

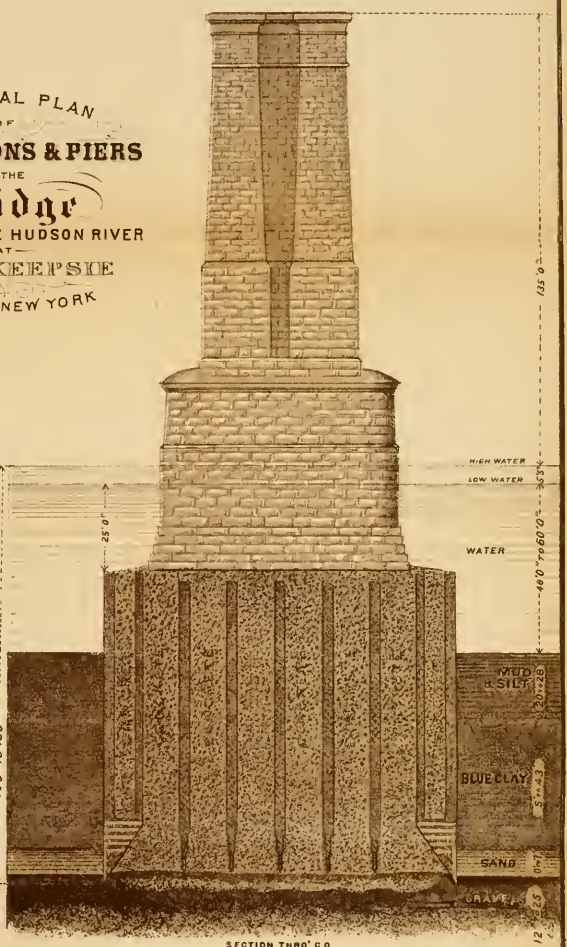
The four river piers are founded on caissons; filled with concrete and resting on the bed gravel—the East pier being 122 feet, the two central 112 feet, and the West pier 97 feet below low tide. The caissons are 60 feet wide by 100 feet long, composed of yellow pine and white hemlock timber, 12 inches square. The lower edge of the ends, sides, and central portions of the caissons is built up solid with timber thoroughly bolted together, for a height of 18 feet, running from a cutting edge, shod with iron to a thickness of 10 feet on the sides and ends and 15 feet



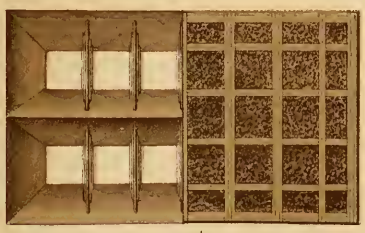
GENERAL PLAN OF FOUNDATIONS & PIERS OF THE Bridge CROSSING THE HUDSON RIVER AT POUGHKEEPSIE STATE OF NEW YORK



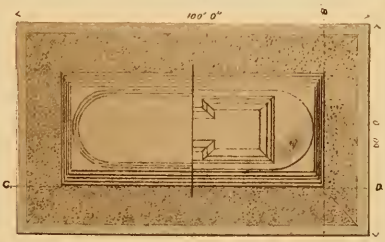
SECTION THRO' A.B
— SCALE 1/192



SECTION THRO' C.D.
— SCALE 1/192



INVERTED PLAN OF CAISSON. — SCALE 1/192 SECTION THRO' E.F.

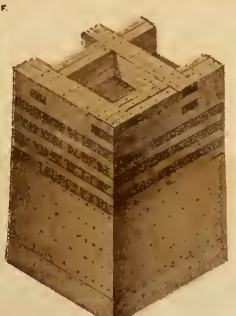


PLAN OF PIER.
SCALE 1/192

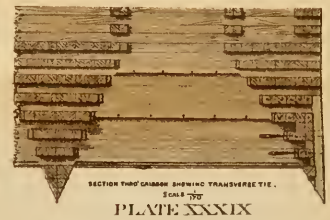
PLAN OF COFFERDAM.
— SCALE 1/192

SECTION THRU' G.H. SECTION THRO' I.J.

FASTENING OF COFFERDAM TO CAISSON.



VIEW OF PART OF CAISSON.
SCALE 1/192



SECTION THRO' CAISSON SHOWING TRANSVERSE TIE.
SCALE 1/192

PLATE XXXIX
TRANS. AM. SOC. CIV. ENG'RS.
VOL. VII. No. CLXXIV
PARIS COMMITTEE

BEG. SCHEGEL, LITH. 85 & 87 JOHN S. N.Y.

in the centre wedge-shaped portion. Transverse walls of timber, commencing 4 feet above the cutting edges, bind the caissons together, dividing the central portion into 12 open compartments. At the height of 16 feet, the transverse and the exterior longitudinal walls are 3 feet thick, and the four interior longitudinal walls 2 feet thick. By this plan of building, the caisson is divided into 40 compartments. The outside and centre line of compartments are 28 in number, placed over the cutting edges. These compartments receive the concrete required for additional weight in the sinking. The remaining 12 compartments, each 12 feet square, extend to the bed of the river, and through them the material is removed by aid of the Clam Shell dredge ; the sinking of the caisson being controlled by excavating from either of the 12 compartments until finally resting in position.

A notable feature of the work is the great depths from which material has to be dredged, and the ease with which the caisson is held in position. The extreme depth of dredging required is one hundred and thirty feet, which is being done without difficulty. The work of sinking the caisson to its foundation having been completed, the services of a diver are availed of, who makes an examination of the river bed through the various open compartments, and upon whose report of the removal of all unctuous materials the work of filling in with concrete begins. It is lowered to the river's bed by the use of the clam-shell dredge, where it is deposited in masses of four to five yards at a time, without damage from wash, forming an artificial base homogeneous with the bed gravel. This filling continues to the top of the caisson, a height of seventy-seven feet in the case of Pier No. 4, now completed, the same being twenty feet below low tide, at which point the granite work begins. The caissons contain each an average of two and a half millions of feet, board measure, of timber, and three hundred and fifty tons of wrought iron, and will contain forty columns of concrete, twelve of which, twelve feet square, extend from the bed gravel to within twenty feet of low tide, the remaining twenty-eight resting upon the cutting edges which are solidly imbedded in the gravel and extend to the same height. The concrete is composed of Portland and Rosendale cement, mixed with sand, gravel and broken stone, in the proportion of five to one.

The examinations and soundings of the river at Poughkeepsie, for the purposes of determining the feasibility of obtaining suitable and safe foundations, were made in 1872, and carried forward to a full and satisfactory development of the entire practicability of the undertaking. On the 20th of January, 1875, a contract was entered into by the Poughkeepsie Bridge Company with the American Bridge Company of Chicago, Illinois, for the completion of the work. New soundings and examinations of the river were made by the latter company at the proposed sites of the different piers, fully confirming those of 1872 and 1873. The

great depths to which it was found necessary to go to reach the gravel, upon which the foundations rest, required a plan by which the dedesired object could be secured without resort to the pneumatic process, which has been accomplished by adopting the present plan of open caisson designed by W. G. Cooledge. By the terms of the contract between the Poughkeepsie Bridge Company and the American Bridge Company the bridge is to be completed and ready for the passage of trains by January 1st, 1881. It is being constructed under the immediate direction of P. P. Dickinson, Chief Engineer of the Poughkeepsie Bridge Company, and W. G. Cooledge, Engineer of the American Bridge Company.

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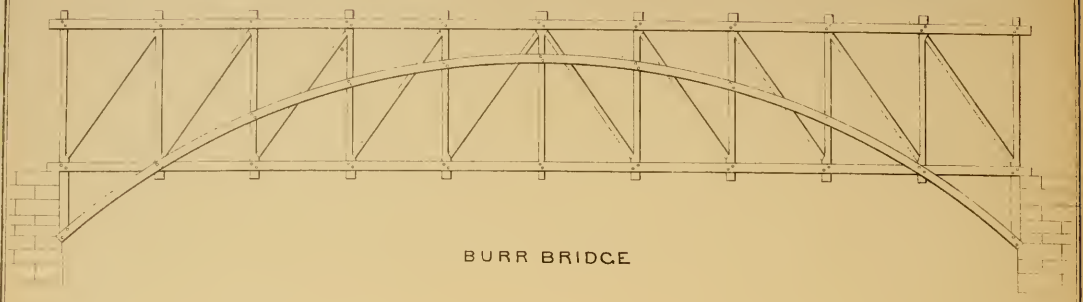
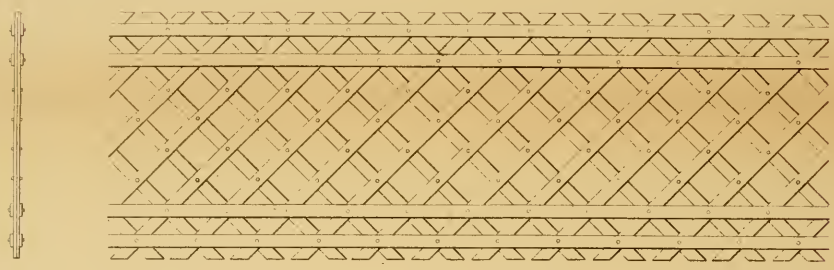
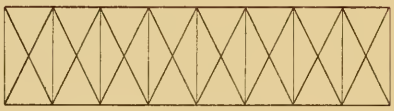
6. *Models of iron pier and caisson foundations, as constructed at Omaha, Leavenworth, Booneville, Fall River, &c. Loaned to the Society by the American Bridge Company.*



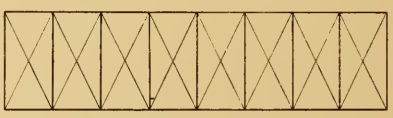
BURR BRIDGE



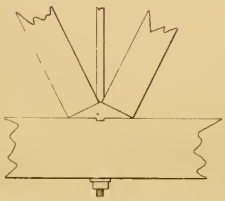
TOWN LATTICE



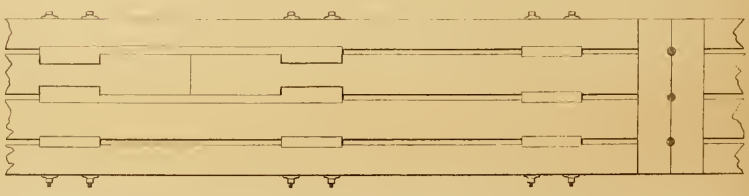
HOWE TRUSS



PRATT TRUSS

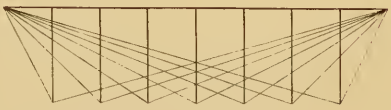


ANGLE BLOCK CONNECTION

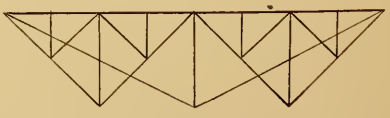


PACKING OF CHORD

DETAILS OF HOWE TRUSS



BOLLMAN TRUSS



FINK TRUSS

WHIPPLE TRUSS

POST TRUSS

BRIDGE SUPERSTRUCTURE.

(See Plate XL.)

The early American bridge builders built almost entirely of wood; they found timber abundant, cheap and good, iron was scarce and dear, and the limited amount of capital forbade the construction of masonry arches where any cheaper substitutes, even of a temporary character, could be used. They built wooden trusses to cross rivers and wooden trestles over ravines; the former to be renewed from time to time, as the timber decayed, the latter ultimately to be filled with earth embankments.

While the earlier truss bridges were of experimental character and of many different designs, two forms soon took a prominent place as the most common and probably the best wooden bridges; these were known as the Burr bridge and the Towne lattice. The Burr bridge was built of square timber; the chords were made of two timbers placed side by side; vertical pieces were placed about ten feet apart and framed through the chords, projecting sufficiently, above and below, to form a connection which would resist tension, and diagonal struts were framed into these verticals between the chords. The Towne lattice was built entirely of plank, usually three or four inches thick, all the connections being made by wooden pins driven through auger holes, the arrangement of parts being generally similar to those of an iron lattice. Both of these bridges did good service, and they are still used for highway bridges in rural districts. They were usually completely covered in, and frequently strengthened by timber arches springing from the masonry several feet

below the trusses, to which they were fastened at frequent intervals. Good examples of these bridges, built as early as the beginning of the century, are still standing.

Another wooden bridge of somewhat later date, but which was built very largely about twenty years ago, was the MaCallum truss. It was in reality a modification of the Burr, the peculiarities being in the upper chord, which was always curved so as to increase the depth of the truss at the centre, and in the use of the so-called arch braces, which starting from the masonry, passed through the lower chord and terminated at different panel points in the upper chord. It was the boast of the inventor that these braces would sustain the bridge even if the lower chord were cut in two, and an instance actually occurred in which the entire lower chord and floor fell under the weight of a train into the river, and the upper portions of the truss were left standing. This bridge was exceedingly stiff and for a time very popular, but it was so complicated that it was customary to make a full-sized drawing on a smooth floor, from which patterns were taken for the framers. It has now gone out of use.

The first real advance from the old wooden trusses was made about forty years ago, when iron rods were introduced to take the tensile strains of the web. This was accomplished in two different trusses, the Pratt truss, in which the web was composed of vertical timber compression members with diagonal rods for ties, and the Howe truss, in which the rods were vertical and the diagonals were wooden struts, one system of bracing being precisely the reverse of the other, and both furnishing the opportunity for perfect counter bracing, in which the Burr bridge was deficient, and which was a necessity in railroad bridges. At first the two systems appeared of equal merit, but the vertical rods of the Howe required a minimum amount of the more costly material, and afforded special advantages for simplicity of detail ; on the other hand, it was found difficult to keep the two iron diagonals of the Pratt truss in proper adjustment. The Howe soon took the place which it still holds, as the standard wooden truss, while it was left for the iron construction of a later period to appreciate the real merits of the Pratt.

The Howe truss may justly be termed the most perfect wooden bridge ever built ; others have been designed of greater theoretical economy ; but for simplicity of construction, rapidity of erection and general utility it stands without a rival. As usually built, the chords

are made up of three to five sticks of timber, 10 to 14 inches deep, and 6 to 8 inches wide. They are placed about an inch apart, the lengths breaking joints, and are fastened together at intervals of about 4 feet with iron bolts and wooden keys, the latter being blocks two inches thick, which are let into the timber half an inch ; in the lower chords the joints in each line of timber are coupled with wooden clamps. On the chords (above the lower and below the upper) rest the cast iron angle blocks ; these are castings as long as the chord is wide, and of triangular section, two surfaces serve as skewbacks for the diagonal braces to rest upon, and the third surface, which comes against the chord, has a lip cast upon it which, fitting into a groove cut across the chord, serves to transmit the strain from the block to the chord. The angle block is cast with two or more holes, through which pass the vertical rods ; these are simply straight rods of round bar iron, with a screw cut on each end ; they pass through the chords, between the different lines of timbers, and the nuts screw up against washer plates of wrought iron placed above and below the chords. The only framing about the braces is to cut them square to length, and the entire truss can be laid out with a square and scratch-awl, and framed with no other tools than a saw, an adze, and an auger. When once properly erected, the only attention required is an occasional adjustment of the nuts so as to preserve an equal strain in the rods of each set.

Mr. Howe built his first bridge, a single highway span of 75 feet in 1840 ; his second bridge was a railroad bridge of seven spans of 180 feet each across the Connecticut river at Springfield, built in the same year. The lower chord was made of planks packed close together with oak trenails ; the panels were only seven feet long and the braces reached across two panels ; the braces were all of the same size as were also the vertical rods ; the angle blocks were of wood. This bridge, though light and badly proportioned, lasted till 1853, when it was replaced by a Howe truss of more modern design, which was still in fair condition in 1874 when it was replaced by a double-track wrought-iron structure.

The Howe and Pratt trusses as originally built were empirical structures like their predecessors; they were proportioned by imperfect rules and without calculation. The simplicity of their design, however, offered inducements for analysis, and the analytical methods now used by American engineers in building iron bridges were applied by the best builders to these more crude structures.

The Howe and Pratt trusses introduced the use of iron for the lightest portions of the truss ; the next advance was to make the entire truss of iron. The general plans of the wooden bridges were adhered to as far as they were applicable to the new material ; the bottom chords, strained in tension, were made of wrought iron bars, and the compression members were of cast iron. The bars of the lower chord were joined together with eyes and pins, and the upper chord was cast in panel lengths with square bearings ; the rods of the web usually passed around the pins of the lower chord, while the connection at the upper end was by nut and screw. The first successful iron bridges were those designed by Squire Whipple, many of the earliest of which are still standing, their skeleton being substantially the same as that still in most common use ; a Pratt truss with the end posts inclined so as to reach over the first panel.

The adjustable truss with cast iron compression members was the real beginning of iron bridge building in America. A large number of bridges of this sort have been built even to a late period by Mr. Francis C. Lowthorp, in which all tensile connections are made with screws.

Up to the year 1850 few iron bridges had, however, been constructed of longer spans than fifty feet.

The first impulse to the general adoption of iron for railroad bridges was given by Mr. Benj. H. Latrobe, Chief Engineer of the Baltimore and Ohio Railroad. When the extension of this road from Cumberland to Wheeling was begun he decided to use this material in all the new bridges. Mr. Latrobe had previously much experience in the construction of wooden bridges in which iron was extensively used ; he had also designed and used the fish-bellied girder, constructed of cast and wrought iron, and which is still in use on the Baltimore and Ohio Railroad ; he had adopted on the older portion of that road the Bollman plan of bridge for short spans, which has since come into extensive use. But for the general plan of bridges west of Cumberland he adopted the plans submitted by Mr. Albert Fink, his assistant.

The basis of this system was the trussed girder, the straight beam with a single post at the centre, supported by inclined rods reaching to each end. Mr. Fink increased the practical length of this style of truss by making each half a secondary trussed girder, and then by treating the quarters and subsequently the eighths in the same way, he extended the single principle of the trussed girder to a truss of sixteen panels ;

the same upper chord acted as the beam for all the systems, but otherwise they were independent.

In both the Fink and Bollman trusses all parts were suspended from the upper chord, and no lower chord was required; they were distinguished by the name of *suspension* trusses. One of the earliest examples of the Fink truss is the bridge over the Monongahela River on the Baltimore and Ohio Railroad, completed in 1853, and still in use. The chords and posts were of cast iron, and the tension members of wrought iron. The bridge consists of three spans, each of 205 feet length, the longest then constructed in this country. All the bridges on the Baltimore and Ohio Railroad were built upon this general plan, and it was adopted on many roads in the South. In many bridges wood was substituted for the cast iron in the parts which resist compression, and this combination resulted in a structure which combined durability with great cheapness. It may be proper to mention here that this plan of truss was particularly designed with the view of making it self-adjustable, when two materials are combined in it, which are differently affected by change in temperature.

While this development in the construction of iron bridges was going on quietly in the more Southern States, during the years from 1850 to 1860, very few iron bridges were then built in the Northern States. The reason for this delay in the adoption of iron for bridge construction must be found in the general prejudice which then existed in the mind of the public, shared even by many engineers, which had been caused by the failure of a badly proportioned iron bridge on the New York and Erie Railway in 1850, and also by the failure of the iron bridge over the River Dee, in England, which took place about the same time. It was difficult for the few engineers, who combatted the Crystallization Theory which was then advanced, to overcome this prejudice. It was some ten years after the commencement of the earlier efforts to which reference has just been made that iron bridges were introduced on the Pennsylvania Railroad, upon the plans of Mr. J. H. Linville. The best of these earlier examples is the bridge over the Ohio river, at Steubenville, which was built in 1862, with a span of 320 feet.

About the year 1867, iron bridge building in America began to assume its present importance. In this year the first iron bridges over the Mississippi were begun, and the scheme for the great bridge at St. Louis began to assume a definite form. At this time the most prominent

designs for iron bridges were of four kinds. The Fink and Bollman suspension trusses, the Pratt truss and the Warren girder. The Howe truss had been built in iron to a limited extent, but it was soon found that however excellent in wood it was poorly adapted to iron construction. In order to obtain greater economy in the web without the use of panels of unusual length, the Pratt truss was built with a double web system (called the Whipple, Murphy, or sometimes the Linville truss), and the Warren girder was either doubled or the floor was suspended by vertical rods from the intersections of the braces with the upper chord. Cast iron was generally used for compression members which were cast of hollow cylindrical form. Mr. Linville, President of the Keystone Bridge Company, had, however, built bridges with wrought iron posts, and the hollow wrought iron riveted column made by the Phœnix Iron Company, had already been received with much favor. Many builders, however, preferred to retain the cast iron top chord, while using the wrought iron posts in the web.

Shortly before this Mr. S. S. Post had designed and patented the Post truss. The details of this bridge were in many respects novel, but the distinctive feature was the arrangement of the posts and ties of the web; the bridge being usually built with a double web system, and the posts being given an inclination across half a panel, main ties across a panel and a half, and the counter ties the same inclination as the posts reversed. This design was the result of careful calculations, and thought to be very economical..

About this time, also, the use of combination bridges became common—this term being applied to bridges in which the lower chord and other tensile members were of wrought iron, the top chord and compression members being wood. The origin of this system of construction may, perhaps, be found in the early suspension trusses of Mr. Fink, with wooden chords and posts. Mr. Fink also introduced what was known as the V combination truss, a Warren girder with top chord and braces of wood and lower chord and ties of wrought iron; this bridge was easily protected from decay by covering the upper chord and principal braces with a tinned roof; it is, probably, the best combination bridge built, and is used largely in many parts of the South, where it has virtually superseded the Howe truss, The Post truss was often built as a combination truss, and the Pratt truss is still built in this way. The first bridge across the Missouri river, built in 1867–69, at Kansas City, by

Mr. Chanute, was an example of a combination double system Warren girder, with curved upper chord.

The introduction of wrought iron posts was soon followed by the use of the same material in the heavy compression sections of the top chord, and the best builders were not slow to realize that the screw adjustments which were important in wooden bridges were of no advantage in an iron structure; the screw connections at the upper ends of the tension rods were accordingly dispensed with, and bridges built with pin connections throughout. The use of cast iron has gradually become less and less, until now many engineers have entirely dispensed with it, making all the connections and details entirely of wrought iron.

The peculiarities of American iron bridges, as compared with those of the European builders, may be traced in no small measure to the fact, that in America the construction of wooden bridges was practically perfected before the building of iron bridges was begun, Many of the features of wooden construction were repeated in iron, sometimes with very unsatisfactory results, and only to be abandoned as the builders became more proficient; but the most prominent feature of American bridge design is the concentration of the material in a few members, and this was realized in the Pratt, Howe and other trusses, before iron bridges were built. Simplicity of skeleton form has been followed from the first; and since the use of wrought iron track stringers has removed the objections to long panels, single systems of bracing have generally been preferred to double, and the simple Pratt truss, of wrought iron with inclined end posts, and all tensile connections made with eye bars and pins, has of late years been built more largely than any other design.

The European systems, on the other hand, have not been without their advocates; riveted structures, copied originally from foreign designs, were early introduced on the New York Central Railroad and some of its connections, and this has ever since been the standard system of construction on those lines. The earlier bridges were generally built with vertical compression members and inclined ties; the latter being so numerous as to give the structure the appearance of a lattice bridge. For the shortest spans riveted plate girders were used. This system of construction has not been without its influence on the designs which are considered more strictly American, and its development has undoubtedly been modified by the standards of other builders.

Plate girders and trellis bridges, built of plates and angle-irons, have now become the favorite forms of iron construction for spans of 60 feet and under, and their use is yearly becoming more common. On the other hand, in trusses of greater length, the builders of riveted work have departed from the European forms of construction and concentrated their material in comparatively few members, the usual design being a species of lattice in which the parts are so few that each diagonal is intersected by only three others—the truss being, in fact, a four-system Warren girder, in designing which the strains of each member are separately calculated in much the same way as is done in the more widely separated members of a pin-jointed truss. One of the best examples of riveted bridges was built in 1874, over the Connecticut river, at Sprinfigeld, Mass., on the piers once occupied by the first Howe truss that ever carried a railroad.

In the early building of railroads and even of late years in the construction of lines in timbered or thinly settled districts, the use of wooden trestle work played a part hardly inferior in importance to that of wooden truss bridges. The plan of trestle work commonly adopted consisted of bents placed from 12 to 18 feet apart, each bent consisting of a sill, four posts and a cap, all of timber 12 inches square; the sill rested on piles or sub-sills according to nature of the foundation; the two inside posts were vertical and placed directly under the rails, and the outside posts were given a batter of about 1 in 4; the posts were framed into the sill and plate with mortise and tenon, and the bent was stiffened by diagonal planks bolted or spiked on each side. Stringers resting on the caps connected the several bents, and on them were laid the ties to which the rails were spiked. This trestle with very slight modifications has been built in all parts of the country, and used to carry railroads across ravines where the cost of earth embankments was too great for the economical demands made on the engineeer. Where the height exceeded about 30 feet the bents were built in two or more stories, an intermediate cap with light longitudinal stringers being placed at the top of each story. For structures of great magnitude special designs were followed, in the best of which the use of mortise and tenon was abandoned, and the different lengths of timber were made with square butt-joints resting directly upon one another. The best known example of this class of structure was the great Portage viaduct designed by Mr. Silas Seymour in 1851, which was so arranged that every

timber could be taken out and replaced without disturbing the stability of the structure.

The first examples of iron trestles were erected in 1853 by Mr. Fink on the Baltimore & Ohio Railroad. There are two of these trestles or viaducts, crossing ravines on Cheat River at an elevation of 250 feet above that river. They are located on grades of 1 in 50, and one of them on a curve of 800 feet radius, and are built entirely of cast iron. The trestle is sixty feet high—the posts are cast in two sections ; the lower has a diameter of 7 inches, and the upper of 6½ inches, with ¾-inch thickness of metal. Every 25 feet there is a vertical post, from the foot of which two inclined braces start ; the braces in the several panels meet at the top in the centre of the twenty-five feet space, giving a support to the stringers bearing the track, every 12½ feet. The length of these trestles is 500 feet, and they are built in sections of 125 feet length ; each section is braced together in such a manner as to permit it to slide—from the centre each way—upon the foundation plates, in order to permit of the contraction and extension of the structure under the influence of changes in temperature.

These structures, presenting an extremely light appearance, have now been in use for twenty-five years, and may, perhaps, be considered the boldest attempt in the use of cast iron in bridge construction.

About a dozen years ago Mr. C. Shaler Smith began building wrought-iron trestles, using Phœnix riveted columns for posts, each bent consisting of two posts with cross struts at intervals of about 30 feet and diagonal tie rods, the bents being placed 30 feet apart, supporting trussed girders, and stiffened longitudinally by struts and diagonal ties ; these trestles were built at first with all longitudinal members of wood so as to avoid any difficulties from thermal expansion, but by omitting the struts in every third or fourth span, there was found no difficulty in making all parts of iron. This general system of construction has now become very common, and iron viaducts of skeleton design are built by all bridge builders, the designs being more or less varied to suit the peculiar requirements of each case. In all of these, however, the same prevailing characteristic is found that marks the truss bridges, the concentration of material in a few members, and the economical advantages of this system are found even greater in lofty viaducts than in long span trusses. The most remarkable example of iron viaducts is the bridge lately built by Mr.

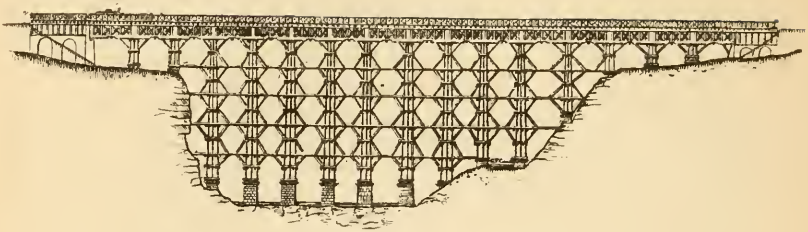
Smith across the Kentucky river, consisting of three spans each 375 feet long, which rest upon iron towers, and carry a railroad at a height of 275 feet above the river.

As early as 1847 Squire Whipple printed with his own hands a memoir on the strains in skeleton structures, in which the general principles of calculating strains, and proportioning the parts of the more common forms of trusses were correctly enunciated. This memoir was the foundation of American scientific bridge building. The practice of American bridge builders is to calculate in detail the strains on each separate member of a truss, preparing strain sheets or skeleton diagrams, on each line in which the estimated maximum strains are marked; in common practice railroad bridges are designed to carry 3 000 pounds for each foot of track with an additional allowance to cover the extreme strains produced by a heavy locomotive on the floor and web systems; it is not unusual, however, to calculate the effects of an actual train, considering the different weights on the wheels. The pin joint system offers the best assurance that the actual strains will agree with the calculations, and renders simple the connection of large sized members, whose use in riveted structures is virtually excluded by the large number of rivets required in the joints.

The practice has been to build the several members of a bridge in the shop, finishing every part. The tensile members are eye-bars with forged heads and eyes drilled to fit accurately on turned pins; the compression members are usually built of plates, angles and channel irons, or of special shapes like the sections of the Phœnix column. Each member is complete as it leaves the shop, and the bridge has only to be put together at its site, little or no riveting being done there; a span of ordinary length will be erected in two or three days.

The last ten years have witnessed the erection of structures of a magnitude which had not been attempted in America till then. The Raritan draw bridge which turns on a central pier and has a total length of 472 feet, and the channel span of the new bridge over the Ohio at Cincinnati, 520 feet long, both designed by Mr. Linville and built by the Keystone Bridge Company; the Rock Island draw bridge, designed by Mr. C. Shaler Smith, and weighing 750 tons; besides the draw bridges, all over 360 feet long, on the Mississippi, and four other bridges across the Ohio with channel spans from 350 to 400 feet, are examples of the application of the more usual forms of construction of

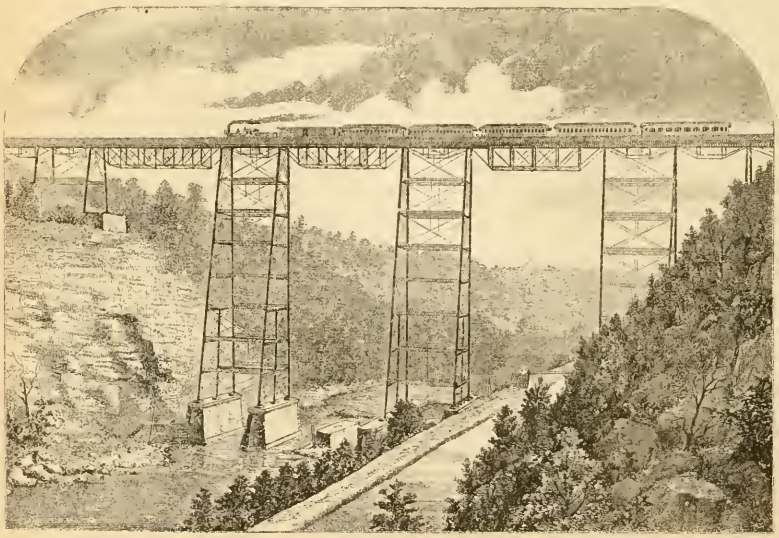
Section.



1852.

PORTAGE VIADUCT

1875



works of unusual size. The St. Louis bridge with its three spans of steel-ribbed arches each about 500 feet long; the stiffened suspension bridge at Pittsburg, and the great steel wire suspension bridge at New York with a clear span of 1600 feet, the cables of which are now in position, are prominent cases in which the engineers have thought best to depart from the usual forms of truss construction and to erect structures specially designed to meet the peculiar requirements of each case.

SUBJECTS EXHIBITED.

7. *Photographs of the old and new viaducts at Portage, New York, and detail drawings of the new viaduct.* SILAS SEYMOUR, Engineer of old viaduct. GEO. S. MORISON, Engineer of new viaduct.

(See Plate XLI.)

The original Portage bridge was the most remarkable timber viaduct ever erected. It was begun July 1st, 1851, and completed, so as to cross with an engine, on August 14th, 1852. The viaduct was over 800 feet long and 234 feet high from bed of the river to the rail, the masonry being 30 feet high, the trestles 190 and the trusses 14 feet. It contained 1 602 000 feet B. M. of timber, 108 862 lbs. of iron in bolts, and 9 200 cubic yards of masonry. Three trestles were grouped together forming a timber pier, and it was estimated that a single one of these piers would sustain 3 000 tons besides the weight of the structure. These piers were fifty feet apart. The general plan was made by Silas Seymour, Chief Engineer, and the drawings and bills of material prepared by H. C. Brundage.

On Thursday, May 6th, 1875, this timber viaduct was destroyed by fire. The destruction of everything above the masonry was complete.

On Monday, May 10th, the contract for the iron work was let to the Watson Manufacturing Company, of Paterson, the bridge to be built according to plans of George S. Morison, C. E. The first iron column was raised June 13th. On July 29th the iron was all in position; on the following day the track was laid across, and on Saturday July 31st, the bridge was tested and thrown open for traffic.

The main principle of the plan may be said to be that which characterizes all American bridge building, and is the leading difference between the works of American and European engineers; the concentration of the material into the least possible number of parts.

The iron viaduct has 10 spans of 50 feet, two of 100 feet, and one of 118 feet, a 50 feet span being placed between each of the long spans. The trusses

are supported by wrought iron columns, the ends of two adjacent trusses resting upon a single column. The pair of columns supporting the opposite trusses are in the same vertical plane, but are inclined towards each other and connected with wrought iron struts 25 feet apart and diagonal tie rods, thus forming a two post bent ; each column is connected with the parallel column of the adjoining bent by a similar arrangement of struts and diagonal ties ; four columns with the connecting bracing are thus made to form a skeleton tower, 20 feet wide and 50 feet long on the top, surmounted by a fifty feet span of bridge, having the same length at the bottom and a width varying with the height of the tower. There are six of these towers, the largest having a total height from masonry to rail of 203 feet 8 inches.

The trusses of the superstructure are proportioned to carry a moving load of 3 000 pounds per running foot, and an excessive load of 5 000 pounds per foot, with a maximum tensile strain of 10 000 pounds per square inch. The towers are built to carry a moving load of 5 400 pounds per running foot (being designed for two tracks); they are also calculated to resist a wind pressure at right angle to the bridge, of 30 pounds per square foot, exerted on the entire surface of the structure and of a train of cars, and one of 50 pounds per square foot exerted on the surface of the structure alone.

The columns rest upon cast iron pedestals, those on the North side of the bridge being secured by dowels to a cast iron plate sunk in the masonry, and those on the South side being placed on rollers, rolling at right angles to the axis of the bridge. The columns are made in 25 feet lengths. They are formed of three plates and four angle irons, with a lacing on the fourth side, so that the interior of the column is accessible for painting. The angles are all $4 \times 4 \times \frac{1}{2}$ inches, and the plates are all 16 inches wide; the thickness of the side plates being varied to provide for the increased strains in the lower sections. The ends of the several lengths are squared and faced, and they rest directly upon one another without joint boxes; the upper end of each length is fitted with two projecting plates which form a tenon ; the length above fits over the tenon plates and is secured to the lower length by a turned pin of $1\frac{3}{8}$ inch diameter passing through carefully bored holes ; this same pin serves for the attachment of the longitudinal rods. A second pin at right angle to this one forms the attachment for the transverse strut and ties. The diagonal ties are everywhere in pairs. The longitudinal strut, which is nearly fifty feet long, is built in the form of a light lattice truss, is two feet deep and one foot wide, with the ends squared and butting against the side of the column.

The towers were raised with no other falsework than that actually used in handling the material of each successive section. Before beginning to raise a tower, a floor of long timbers reaching from pier to pier and loose boards was laid at the site of the tower ; on this floor was

erected a frame work 30 feet high, and composed of two bents, one on each side of the tower; each bent consisted simply of two posts 48 feet apart and a cap 55 feet long, braced with planks across the corners. The lower lengths of the columns were then lifted into position; the transverse and longitudinal struts put in place and the diagonal ties put on. A gin pole 55 feet high was then lashed to each column, and these gin poles were used to transfer the floor and frame to the top of the now completed lower section of tower. The same operation was then repeated with the second lengths of columns, which were placed over the tenon plates of the lower length, and secured by the pins. When the second section of the tower was completed, the frame was used to raise the gin poles; the floor and frame were then raised again, and the process repeated till the tower attained its full height. The last tower raised, weighing 277 000 pounds, was entirely erected in 11 days, one day only having been previously spent in preparing the staging for the first section.

To erect the long spans, combination Pratt trusses were built, the top chords of which were made of four pieces of pine 4 × 10 inches, packed in pairs, and sprung about 4 feet apart in the centre; the bottom chord was of straight parallel eye bars and the posts V shaped; the form of the top chord made the truss stiff without lateral bracing. These trusses were put together below, and raised by block and falls to the bottom of the upper section of the towers, where they were placed, resting upon the transverse struts, two being used for each span. A suitable staging was then erected on them, and the permanent truss was put together, the materials being run out from the end of the bridge.

The trusses are of the simple Pratt pattern. One end of each long truss is bolted to the iron capital of the column and the other is placed on rollers, but connected with the next truss by iron loops passing over the end pins of each span, and allowing only the amount of motion needed for expansion. The short spans over the truss are bolted to the capitals at both ends. The end pins of the 50 feet spans are placed 6 inches from the centre of the column, and those of the long spans only 3 inches, so that under a full load the centre of weight comes directly in the line of the centre of the column.

The total weight of iron in the bridge is 1 310 000 pounds, divided as follows:

Towers		897 550
10 spans 50 feet each	197 420	
2 " 100 " "	128 910	
1 " 118 "	86 120	
Total weight of superstructure		412 450
Total		1 310 000

The amount of timber in the floor, foot-ways and railing is 112 318 feet of oak and 18 300 feet of pine (B. M.), while 27 987 pounds of iron were used in bolts and washers, the heavier bolts being all bolts taken from the ruins of the old bridge.

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8. *Photographs of iron double track railroad bridge over the Delaware at Easton, and detail drawing of double track iron bridge on Erie Railway; built by* Messrs. Kellogg & Maurice.

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9. *Photograph of double track iron bridge at Corning, on the Erie Railway; built by* Charles Macdonald, C. E.

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10. *A collection of bridges built by Delaware Bridge Co.* Charles Macdonald, C. E. President.

(See Plate XLII.)

The group exhibited by the Delaware Bridge Co. comprises:

1st. A photograph of the Passaic Draw Bridge, near Newark, N. J.

2d. A photograph of the Oak Orchard Viaduct, on the Rome, Watertown and Ogdensburg Railroad, New York.

3d. A photograph of the Rockville Bridge, on the Pennsylvania Railroad, near Harrisburg, Pa.

4th. Drawings of some important details of the bridges illustrated by the above photographs.

Passaic Draw Bridge.

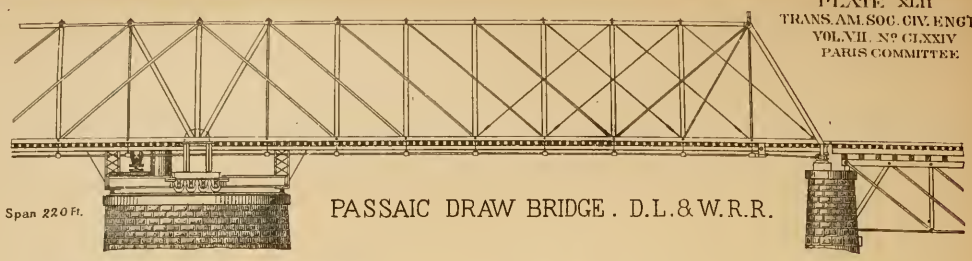
This is a wrought iron double track structure, crossing the Passaic River at Newark, on the line of the Morris & Essex Railroad. There are three trusses, sustaining the tracks upon iron beams suspended from the lower chords.

General Dimensions.

Length of trusses from centre to centre of end pins ..... 220 ft. 6 in.
Height of trusses from centre to centre of chords ..... 22 ft.
Width of bridge from centre to centre of outer trusses ..... 30 ft.
Height of rail above the water ..... 45 ft.

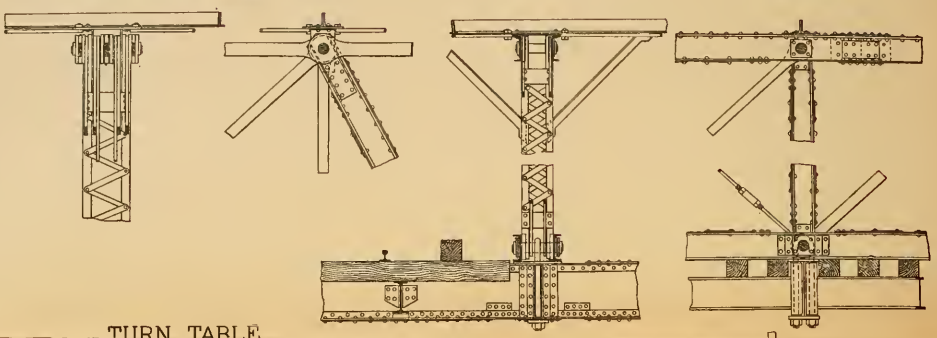
Weights adopted for Calculation.

Dead load per lineal foot of bridge ..... 2 000 lbs.
Live load, per lineal foot, covering both tracks throughout entire length ..... 5 000 lbs.
Live load, per lineal foot, covering both tracks for one half the span ..... 7 000 lbs.

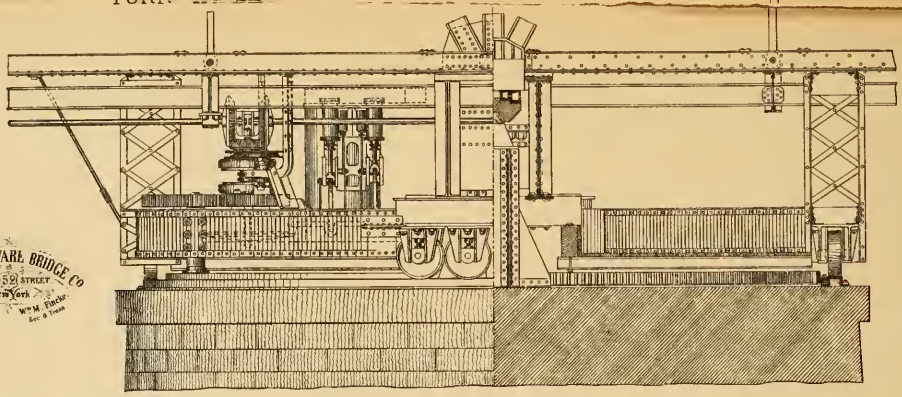


Span 220 Ft.

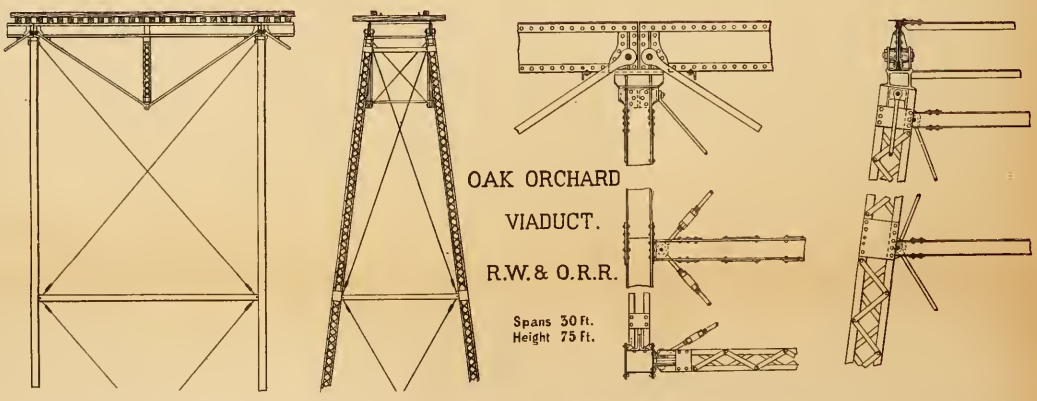
PASSAIC DRAW BRIDGE. D.L.&W.R.R.



TURN TABLE

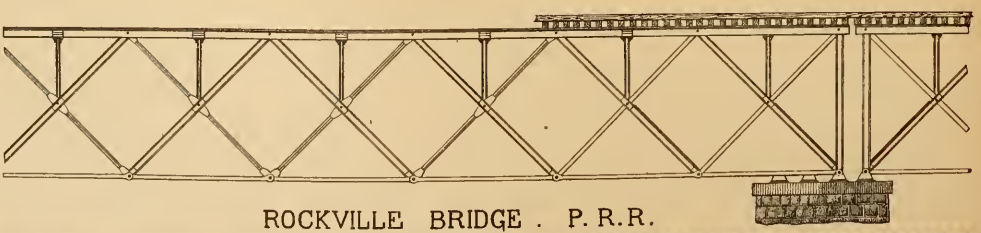


THE DELAWARE BRIDGE Co
WALL 52 STREET
New York
C. Macdonald Pres. & Chf. Eng.
Wm. M. Fincke Sec. & Treas.

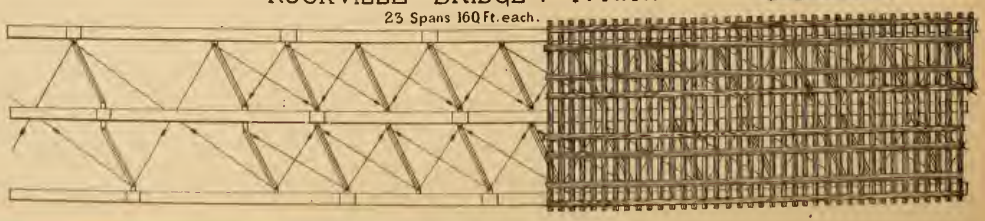


OAK ORCHARD
VIADUCT.
R.W.& O.R.R.

Spans 30 Ft.
Height 75 Ft.



ROCKVILLE BRIDGE. P.R.R.
23 Spans 160 Ft. each.



When the bridge is open all the dead load is transmitted to the central support, and the strains are determined as in the case of a beam supported in the middle. When the bridge is shut and the wedges adjusted, the extremities are brought to rest only, and the strains due to dead load are not materially changed ; the effects produced by the rolling loads are now determined under the assumption that the bridge is supported at the centre and extremities ; and finally, the maximum strains are obtained by adding the strains due to fixed and rolling loads with their proper sign :

Weight of Iron in the Structure.

Upper chords	45 000 lbs.
Lower chords	52 000 "
Posts	65 780 "
Diagonal bars	48 800 "
Pins	5 900 "
Upper lateral system	15 800 "
Lower lateral system	4 800 "
Portals	2 600 "
Cross floor beams	68 970 "
Longitudinal floor beams	41 120 "
Weight of iron in trusses	350 770 lbs.
Weight of iron in turn-table	107 690 "
Total	458 460 lbs.

The trusses are of the " Whipple " type, with the end posts inclined, and with two inclined posts and a vertical at the central point of support. The chords are, for the most part, made up of two 10 inch channels and a cover plate on one side, with open lattice work on the other, forming a trough shaped section. In the centre panels of the upper chord, where tension alone exists, eye bars are used ; all other connections in the chords are designed to resist both tension and compression. The lower chords of the centre truss abut against a casting which forms the upper portion of the turn-table, and are secured to it by angle iron lugs. The lower chords and central posts of the outer trusses are riveted at their intersection to splice plates, making a continuous wrought iron connection. The connections at the abutment ends are also riveted. Vertical posts are made up of channels latticed on both sides, forming a rectangular section open on both sides to inspection. The ends are reinforced, and pin holes bored for connection with the chords. No joint boxes are used.

The dead weight of the bridge is transmitted to the revolving surface of the turn-table through the casting at the centre of the lower chord of the middle truss; that portion is borne by the middle truss directly, while the outer trusses rest upon the extremities of two plate girders connected

on each side the center by diaphragm plates and lugs; by this means the entire weight of the outer trusses and cross-girders may be suspended upon twelve vertical bolts passing through holes in the sides of the central casting. This casting rests upon conical steel rollers enclosed between steel rings grooved to fit the coning of the rolls, and having half an inch play between: upon these rollers the bridge revolves. The lower ring is fitted to a cast iron seat having a hemispherical cavity on the under side to receive a corresponding cast bearing block which distributes the weight upon a wrought iron pintle extending to the masonry. Under each end of the cross girders are four trailing wheels adjusted so as to bear lightly upon the track. When one line of rails is loaded, these wheels sustain a portion of the weight, but not when the bridge is turning.

Attached to the lower side of the base girders forming the ends of the bridge, are castings containing movable wedges having one and a half inches vertical play; they are beveled to fit bed castings attached to piers so that when they are driven to a bearing, horizontal displacement becomes impossible. The free ends of the track are lifted simultaneously with the wedge movement.

The bridge may be operated either by steam or by hand, as desired. A double cylinder engine drives a vertical shaft to which are attached two friction clutches. By throwing the upper one into gear a horizontal line of shafting is made to actuate the wedges and rail lifters. By shifting to the lower friction, motion is communicated to a driving pinion working into cast toothed segments which are bolted to the masonry through the track.

A vertical shaft, for working by hand, is placed between the rails; it communicates with the wedge gear by a chain wheel, and with the driving pinion by a small intermediate.

The time required to withdraw the wedges and swing the bridge does not exceed two minutes.

This structure was erected in place of an old wooden bridge, during the winter of 1876–77, and the traffic of the railroad was not seriously interrupted during the progress of the work.

Oak Orchard Viaduct.

A single track wrought iron structure on the line of the Rome, Watertown and Ogdensburg Railroad, near Rochester, New York.

General Dimensions.

Total length between abutments	690 feet.
Twenty-three spans, each	30 "
Height of trusses	9 "
Width of bridge, centre to centre of chords	10 "
Height of rail above the water	80 "

Weights adopted for Calculation.

Dead load per lineal foot	500 pounds.
Rolling load consolidation engine in a length of 50 feet	150 000 "

Weight of Iron in the Structure.

One span of 30 feet	7 000 pounds.
One bent 75 feet high	12 000 "
Total weight in the entire viaduct	365 000 "

In general type it resembles similar structures in other parts of the country, and is an economical distribution of material for crossing ravines. The principal bents are 75 feet in height from masonry to base of rail; they are framed in two lengths and spliced on the ground by riveting cover plates through the flanges of the channels. All the connections at these splices are of wrought iron. The main posts are made up of two 10-inch channels latticed at each flange and entirely open and accessible to painting and inspection. Base castings are anchored to the masonry to obviate the necessity of a horizontal strut at the foot of the bents. The 30-feet spans consist of plate girders 20 inches deep trussed by a centre post, and eye-bars. The tension transmitted through these bars is applied to the web of the girder at a point below the centre, with a view of counteracting the bending effect produced by the driving wheels of a locomotive on a half span. Changes due to temperature are provided for by firmly bracing each alternate pair of bents and connecting the 30-feet span between them with the caps of the posts, thus forming a horizontal strut and constituting with the two bents a rigid pier entirely independent of the rest of the structure. The 30-feet spans between each of these piers are attached to post caps by bolts passing through slotted holes, allowing ¾ inch play.

The time expended in the erection of the structure was three weeks. The iron was delivered at the bottom of the ravine and lifted into place by means of a movable projecting derrick.

Rockville Bridge.

A double track wrought iron structure crossing the Susquehanna River five miles above Harrisburg, Pa., on the line of the Pennsylvania Railroad.

General Dimensions.

Total length between abutments	3 675 ft.
21 spans	156 ft. 6½″
2 spans	151 ft. 0½″
Height of trusses centre to centre of chords	19 ft. 7″
Number of trusses per span	3.
Width of bridge centre to centre of outer trusses	22 ft.
Height of rail above the water	45 ft.
Angle of skew	68°

Weights adopted for Calculation.

Dead load per lineal foot	2 750 lbs.
Rolling load per lineal foot	6 000 "

In the determination of maximum strain in the upper chords, it was assumed that the bending effect due to excess of locomotive weight was added to the direct compression.

Weight of iron used in the structure.

For one span of 156 feet 6½ inches.

Upper chords	100 790	pounds.
Lower chords	57 930	"
Vertical end posts	8 770	"
Inclined posts	45 290	"
Counter braced diagonals	12 670	"
Diagonal tension bars	15 670	"
Sub-posts	8 030	"
Pins and nuts	6 750	"
Lateral struts	15 030	"
Lateral rods	7 000	"
Lateral bolts and nuts	1 850	"
Wind bracing	5 400	"
Shoes at feet of end posts	2 450	"
Bed plates	1 200	"
Expansion rollers	670	"
Total iron in one span	289 500	"
Total iron in the bridge	6 670 000	"

There are three trusses in each span, with the tracks so disposed upon them as to bring an equal distribution of load upon each.

The top chords are of 12 inch channels, with thickening plates, covers upon the top and the lower side latticed. The web consists of a double system of main post and tension bars, inclined at an angle of 45 degrees, and connected at their intersection midway between the chords, by pins. At their intersection with the chords they are also connected by pins, dividing the spans into eight main panels of 19 feet 6 inches each. From the middle intersection of the web members a vertical sub-post extends to the under side of the upper chord, forming a support for that member half way between the main panel points. The chord splice occurs at this point, and at each splice the ends abut squarely, and cover plates are riveted on to insure a continuous member. The braces are built of channels, latticed on two sides, forming a rectangular section, accessible to inspection on all sides; the ends are reinforced, and they are bored for upper, middle and lower pin connections. Where tension only occurs, eye-bars are used, instead of latticed channels. Bottom

chords are made of eye-bars, in panel lengths of 19 feet 6 inches, disposed both inside and without the jaws of the braces, so as to insure a uniform distribution of strain upon each eye-bar in a panel.

Lateral strnts and rods are attached directly to the pins by U-shaped nuts, and a vertical bolt, no cast iron being used.

The rails are laid upon cross timbers, of oak, 7×14 inches, spaced 21 inches, centre to centre, and resting directly upon the top chords, which were proportioned to resist this extra bending strain.

This structure was built to replace a wooden bridge constructed upon the general type known as the Howe Truss. The terms of the contract required that the new bridge should be erected without interfering with the traffic of the railroad, or in any way endangering the stability of the old structure until the trains were transfered to the new; after that, the old material was to be taken apart and placed upon trains for removal. On the 24th of May, 1877, the Delaware Bridge Company signed a contract with the Pennsylvania Railroad Company, for furnishing the material, and the completion of the structure by the 1st of December of the same year. On the 11th of August the first span was in place; and on the 18th of November following, the last span was completed, and regular traffic began over the entire length of the new bridge. The erection began at the middle of the bridge, and was continued simultaneously, with but few delays, to the two extremities. Two movable derricks served to place the iron in position, and afterwards to take down and load the old material. During the progress of the work, the average number of trains passing over the bridge per day was sixty-four, and no interuption of traffic occurred,

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11. *Drawing of the Illinois and St. Louis Bridge.* James B. Eads, Chief Engineer.

The supporting members of the superstructure consist of twenty-four steel arches, eight in each span. Each arch is composed of a large number of straight tubes, with slightly beveled ends, and to the casual observer appears to be a continuous curved tube. The arches are arranged in four ribs, each rib consisting of an upper and lower member connected by a system of wrought iron diagonal bracing. The axes of the upper and lower members form parallel curves twelve feet apart. Each span has four ribs. The whole number of tubes is 1 036. A tube is about twelve feet long, and comprises a steel envelope $\frac{1}{4}$ inch thick, and 6 rolled steel staves, varying in thickness from $2\frac{1}{8}$ inches at the springing to $1\frac{3}{16}$ inches at the crown. The exterior diameter is always 18 inches. Steel or wrought iron sleeve couplings firmly unite the tubes by means

of parallel grooves turned on the ends of the staves. Steel pins through the couplings and staves receive the ends of the main brace bars. Each main brace consists of two heavy rolled iron bars, about two feet apart, with T bars and lattice bracing between. The two lowest tubes of each member are screwed into heavy wrought iron skewbacks which rest on cast iron bed plates, and by long steel or iron bolts are anchored to the masonry. All these bolts are 5¾ inches in diameter, and from 22 to 36 feet in length. In the channel piers the bolts pass through the masonry and unite the two skewbacks. About 2 200 tons of steel and 3 400 tons of iron are used in the whole bridge.

The length of the West span is 504.07 feet, of the East span 504.84 feet, and the centre span 522.39 feet, measured on a line through the centers of the lower skewback pins.

The roadways of the bridge are carried by vertical struts made of braced iron channel bars resting directly upon both ends of the steel pins already mentioned. The upper roadway is 54 feet wide.

The bracing between adjacent ribs consists of tubular iron struts screwed to the ends of the steel pins, and diagonal steel tension rods. The diagonals are in horizontal and vertical systems. The vertical system serves to distribute live loads from rib to rib, and renders it possible by screwing up the ties to throw the entire weight of one rib upon the others, and take the rib to pieces; a tube injured during erection was taken out after the entire span had been completed, and a new tube was inserted. Each pair of ribs supports a railroad track. To increase the lateral stability a horizontal wind truss the full width of the bridge extends across each span immediately below the upper roadway. It is a lattice girder made wholly of iron. The chords of each truss are united at the piers and rest upon the channeled surface of a cast iron block which is fixed in position by large wrought iron bolts running to the right and left and deep into the solid masonry.

All the anchor bolts and sleeve couplings were tested; the steel bolts to 40 000 lbs. per square inch, the iron ones to 18 000 lbs. per square inch. A large proportion of the staves were subjected to an actual compression of from 50 000 to 60 000 lbs. per square inch. Specimen bars of all the material used were tested in great numbers and records kept. Over thirty model steel tubes and hundreds of steel cylinders from American and European manufacturers were tested in the investigations.

The public test of the bridge consisted in placing fourteen locomotives simultaneously upon the tracks of a single span.

The arches were erected by building the ribs out from the skew backs, partly self supported, but mainly held by iron cables passing over towers built on the tops of the piers. All the adjustments were made with the greatest accuracy, and the arches were all closed in the centers of the spans by the use of "extension" tubes capable of being lengthened or shortened by means of solid wrought iron cylinders filling the interior of

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PLATE XLIII

GIRARD AVENUE BRIDGE.

tubes and furnished with right and left handed screws. The contract of making and erecting the superstructure was taken by the Keystone Bridge Company of Pittsburg, Pennsylvania. Great difficulty was experienced in obtaining steel and iron of the required shape and strength, but in spite of every unforseen trouble, every part of the plan was faithfully executed.

In giving to the Chief Engineer, Capt. James B. Eads, the pre-eminent place as the designer and controlling spirit of the enterprise, we must not fail to mention the eminent services of his assistants, Col. Henry Flad and Mr. Charles Pfeifer.

The bridge was publicly opened on July 4, 1874. The cost of the bridge, including a large amount of interest and commission accounts, was not far from $10 000 000.

A full account of the Illinois and St. Louis bridge, by Professor C. M. Woodward, of St. Louis, is nearly ready for the press, from which the above account, as well as that of the foundations, has been taken. The work has been undertaken at the request of Capt. Eads, and all questions of fact will be endorsed by him. The history of the bridge will include the organization of the company, description of the work at all stages, difficulties met, preliminary tests, and tests of working pieces, process of erection, theory of the arch, and the calculations. It will be illustrated by fifty or sixty large plates and numerous small cuts.

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12. *Photographs of Girard Avenue Bridge, Philadelphia, designed by* Clarke, Reeves & Co.

(See Plate XLIII.)

There are seven lines of trusses or girders placed side by side 16 feet apart, and united by horizontal and vertical bracing.

These trusses are of the double Pratt system. The upper compressive members and the vertical posts are Phœnix flanged columns, united by cast-iron joint boxes. The lower chords and diagonals are weldless eye-bars, die forged by hydraulic pressure. Upon the top of the posts, 12 feet apart, are laid heavy 15-inch rolled beams, and upon these longitudinally, 9-inch beams placed 2 feet 8 inches apart; these are covered transversely with rolled corrugated plates ¼ inch thick, corrugated 1¼ inch high by 5 inches wide; these form an unbroken iron platform upon which the asphalte concrete is placed.

The dead load of the structure with a moving load of 100 pounds per square foot makes a total load of 30 000 pounds per lineal foot, carried by seven trusses.

The limit of strain is 10 000 pounds per square inch, reduced to 6 000 pounds per square inch as the compressive limit on parts. All points of contact are either planed or turned. The pins are of cold-rolled iron,

and the limit of error between pin and hole is one sixty-fourth of an inch.

The iron used in this bridge is double refined, capable of bearing the following tests : ultimate strength, 55 000 pounds to 60 000 pounds per square inch ; no permanent set under 27 000 pounds to 30 000 pounds per square inch ; average reduction of area at point of fracture 25 per cent, The elongation of a 12-inch bar is 15 per cent., and the cold bend of a 1½-inch round bar before cracking, 180°, or hammered flat.

The floor is made of corrugated iron plates covered by 4 inches to 5 inches of asphalt, making a water-tight surface. The 100 feet of width is divided into 67½ feet of carriage way, and two 16½ feet sidewalks. The roadway is paved with granite blocks in the usual manner, except that it is divided into seven ways by two lines of iron trackways next the sidewalks for horse cars, and five lines of carriage tramways, made of cut granite blocks 1 foot wide, laid to a 5-feet guage. The gutters and curb-stones are of fine cut granite. The sidewalks are covered for 10 feet of their width with black Lehigh County slate tiles, 2 feet square, laid diagonally. On each side of the tiles are spaces 2 feet wide, which were originally laid with encaustic tiles. After one winter's frost, these tiles became so much shattered that they were removed and white marble tiles substituted in their place. The curb-stone, 18 inches wide, makes up the remainder of the 16½ feet.

The sidewalks are separated from the roadway by railings of galvanized iron tubes with bronze ornaments, and are supported by cast-iron standards at every 6 feet. Every eighth standard is prolonged into a lamp-post. There are eight refuge bays, each of which contains a cluster of six lamps, the supporting shaft rising through an octagonal seat, which forms its base. The outer balustrade and cornice is of cast-iron with bronze open work panels, and treated in a highly ornamental manner.

The construction of the permanent new bridge began May 11th, 1873, and July 4th, 1874 it was formally opened for public travel.

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13. *Photographs of Ice in Delaware River, showing piers of bridges with superstructure gone, near Port Jervis, and of new iron bridge erected at same point.* George S. Morison, Engineer.

The bridge was destroyed at 7.40 A. M., March 17, 1875. It was a double track iron bridge of five spans, one through span over the Delaware and Hudson Canal, and four deck spans over the Delaware River. The span over the canal was undisturbed. The ice lifted the four river spans from the piers, leaving the masonry uninjured. The East span settled down on the ice, remaining within a few feet of its proper position ; the other three were carried down the river on the floating ice

LOUISVILLE BRIDGE
PLATE XLIV
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and left at various points from four to twelve miles below. The West span was 160 feet long in the clear, the others each 150 feet, the rail being about 50 feet above the ordinary stage of water.

The work of reconstruction was begun at once, and a temporary bridge consisting of two spans of trestle and two of Howe truss was ready for use on Saturday, March 27th. The plan for a new permanent structure was determined on and proposals received, on the day of the disaster, and a contract was made with the Watson Manufacturing Company of Paterson, N. J., to build the new bridge by the pound. The plans were virtually completed and the bills of material were on the way to the rolling mills on the 18th.

The first span, 166 feet over all, was entirely shipped on Saturday, April 3d, and swung Wednesday, April 7th.

The second span, 156 feet over all, was swung Monday, April 12th.

The third span was swung Saturday, April 17th.

The fourth span was swung Monday, April 19th.

The permanent floor could not be put on till Sunday, April 25th, and on the following day the double track was completed, precisely 40 days after the destruction of the old bridge, the new iron bridge having been manufactured in 30 days, and erected in 32 days from the date of the contract.

The long span weighs 304 422 pounds, and the others averaged 265 641 pounds, making a total of 1 101 345 pounds, besides cast iron bed plates.

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14. *Photograph of Iron Railroad Bridge over the Ohio River, at Louisville, Ky.* Albert Fink, Chief Engineer. F. W. Vaughan, Assistant Engineer.

(See Plate XLIV.)

This bridge crosses the Ohio River at Louisville, connecting the States of Kentucky and Indiana. Its total length is 5 294 feet, consisting of twenty-seven spans, of various lengths from 50 to 250 feet, on the Fink plan, placed below the grade of the road, and 2 channel spans, one 370, the other 400 feet long, placed above the grade of the road. This bridge was commenced in the fall of 1867, and completed in the spring of 1870. The channel spans are of a peculiar design, a modification of the triangular plan of bracing—by introducing auxiliary trusses between the main braces. The feet of the main braces are 56 feet 7¼ inches apart, and by the auxiliary trusses this space is divided into four parts, giving a support to the stringers upon which the track rests every 14 feet 1⅜ inches. The height of the truss is 46 feet. Each side of the bridge consists of two separate trusses, which are simply bolted together. The chords are of cast iron, the braces having to resist compression of wrought iron, and the tension members also of wrought iron.

The following is a statement of the quantity of iron in some of the principal spans :

	Cast iron.	Wrought iron.	Total.
400 feet span.	570 585 lbs.	834 880 lbs.	1 405 465 lbs.
370 " "	480 953 "	640 095 "	1 121 048 "
245½ " "	216 119 "	215 803 "	431 922 "
180 " "	123 308 "	91 259 "	214 667 "
150 " "	101 453 "	70 224 "	171 677 "
100 " "	58 725 "	29 183 "	87 908 "
50 " "	7 557 "	15 801 "	23 358 "

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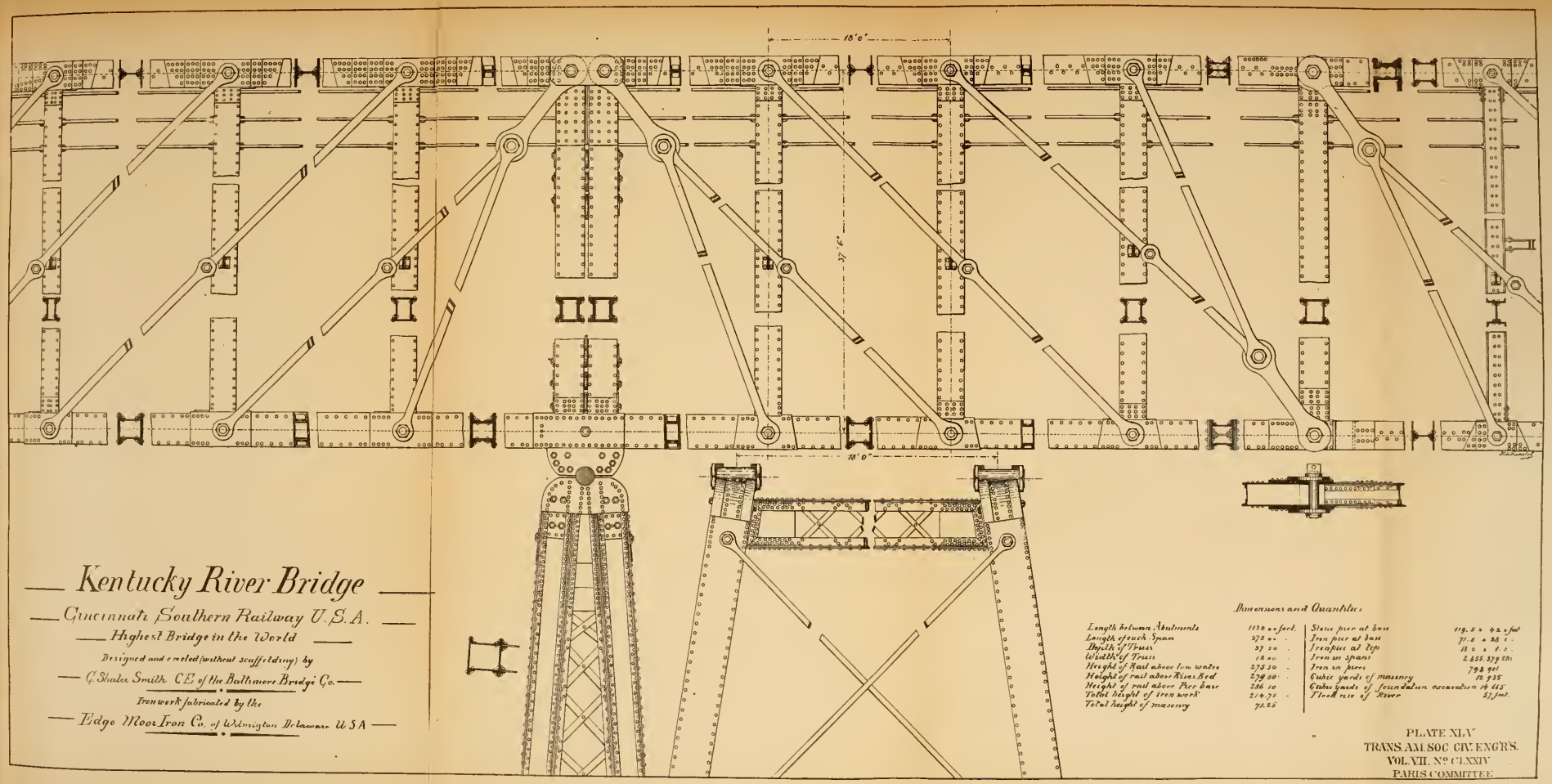
15. *Detail Drawing of the Rock Island Draw-Bridge. Designed and built by* C. Shaler Smith, C. E.

The Rock Island Bridge crosses the Mississippi River, connecting the cities of Davenport, Iowa, and Rock Island, Illinois. It was built for the United States Government in 1871, and accommodates the highway travel on the lower floor, and the railway service on the middle deck. The pivot span is 368 feet in length ; weighs, above the rollers, 1 505 000 pounds, and has two floors, respectively 37 and 23 feet wide. This great wind surface, combined with the weight (the entire rotating mass weighs 1 564 000 pounds), and the fact that one end of the span is under the lee of the United States Depot Arsenal, and that the bridge is exposed to heavy wind storms, which, when blowing from the North-east, East or South-east, act on only one end of the span, made the designing of a suitable turn-table a matter of the utmost importance. The plan decided upon was that shown in the drawing here described. A cast-iron circular girder, 30 feet in diameter, 5 feet in depth, web 2 inches thick, and flanges 15 inches wide, rests upon a live ring composed of 34 wheels, each 30 inches in diameter and 14 inches face. The traveling weight borne by each of these wheels is 44 250 pounds. To secure perfection of action, a revolving frame, the full size of the circular girder, was first constructed at the machine shop where the turn-table was built, and on this the girder and wheel track were planed to an exact level. The wheels were all turned to a gauge, and the entire table fitted together on the revolving frame, so as to test the fitting of every part.

The span is rotated by two hydraulic rams, each of 10 feet stroke and 5 inches diameter of piston. These are placed over the circular girder, one on each side of the span, in a vertical position, and are worked by a double cylinder engine, each cylinder being 6 x 8 inches. The force pumps are four in number, each with 1½ inch piston. The rams are reciprocal, each being the reservoir for the other, and the office of the pump is to transfer the liquid from one ram to the


18' 0"
37' 6"
18' 0"
Kentucky River Bridge
Cincinnati Southern Railway U.S.A.
Highest Bridge in the World
Designed and erected (without scaffolding) by
C. Shaler Smith C.E. of the Baltimore Bridge Co.
Ironwork fabricated by the
Edge Moor Iron Co. of Wilmington Delaware U.S.A.
Dimensions and Quantities
Length between Abutments 1130 0 feet.
Length of each Span 373 0 "
Depth of Truss 37 50 "
Width of Truss 18 00 "
Height of Rail above low water 272 50 "
Height of rail above River Bed 279 50 "
Height of rail above Pier base 256 10 "
Total height of iron work 214.75 "
Total height of masonry 71.25
Stone pier at base 119.5 x 42 feet
Iron pier at base 71.5 x 38 1 "
Iron pier at top 13 0 x 4 0 "
Iron in spans 2,455,379 lbs
Iron in piers 798 901
Cubic yards of masonry 15 935
Cubic yards of foundation excavation 14 445
Flood rise of River 57 feet.
PLATE XLV
TRANS. AM. SOC. CIV. ENG'RS.
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other. Both rams are thus under the same pressure at all times, and hold the span in equilibrium, except while the pumps are shifting the fluid from right to left, or *vice versa*. Owing to the very low temperature at which the span is often required to be moved, a non-freezing liquid was necessary in order to operate the rams. A mixture of glycerine and water—fifty per cent. of each—was found to be the best for this purpose. The power of the rams is transferred to the pier by means of a wire rope. 1½ inches diameter, arranged as in an Armstrong crane. The frictional resistance to rotation at the centre of the live ring wheels is 7 $\frac{36}{100}$ pounds per 1 000 pounds of superincumbent weight.

The pivot span supported by this turn-table is peculiar in that it is proportioned without dead weight reactions under the end supports, that the top chord is composed entirely of eye-bars, that every panel point in both chords is hinged vertically, and that all lateral connections are hinged horizontally.

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16. *Detail Drawing and Photographs showing method of erection of the Kentucky River Bridge. Cincinnati Southern Railroad. Designed and built by* C. Shaler Smith, C. E. (See Plate XLV.)

This bridge crosses the cañon of the Kentucky river, 112 miles South of Cincinnati, at an elevation of 275 feet above the low water level of the river. The six photographic views show the mode of erection of the structure at its various stages, and the drawings appended portray the typical parts of the truss and piers. The peculiarities of the truss are as follows: The middle portion is a continuous girder 525 feet long, supported by piers placed 375 feet apart, and supporting two discontinuous spans, each 300 feet in length, at the ends of projecting cantilevers extending 75 feet from each pier. The upper and lower chords are riveted throughout, except at the cantilever points where the upper chord is hinged and the lower chord fitted with sliding tenons, so that motion from load or thermal changes may be uninterrupted. All connections of the web members to the chords are hinged. The piers are composed of four legs each, and are given a base sufficient to prevent tension on the leeward legs under any condition of load or violence of wind. For convenience during erection, and to accommodate thermal changes, each pier pedestal is placed on a double set of friction rollers, so as to admit of motion in any horizontal direction. The connection between span and pier consists of a pin 12″ in diameter, thus making a fixed joint and permitting a rocking motion only. The piers were placed 375 feet apart when the thermometer was at 60°, and are perfectly vertical only at this temperature. The additional strains caused by the expansion of the truss and momentum of a train weighing 1 100 tons and supposed to be brought to a rest on the bridge after entering it at 30 miles per hour, have been

computed, and the necessary extra material added to the legs and braces to resist them. At the hinging points both web systems are united in one, in order to avoid any ambiguity of strains; and to render this more exact, the union is effected by means of a hinged link placed at the angle of the resultant between the tie bars of both systems. The action of spans, piers, and hinges, under loads and during changes of temperature, leaves nothing to be desired, and the novelties in construction and mode of erection proved to be practical successes.

17.—*Drawings and Details of Street Bridge over the Pennsylvania Railroad at Forty-first street, Philadelphia, Penn.* WILSON BROS. & CO., Engineers. (See Plate XLVI.)

The superstructure of this bridge is constructed on a stiffened triangular truss system, entirely of wrought iron. It has two trusses with outside sidewalks, and an ornamental finish at the entrances of cast and galvanized iron fastened to the wrought iron framework. The floor beams are of wrought iron, suspended built beams, placed across from truss to truss at the panel points. Upon these rest longitudinal floor joists of white pine. The roadway and sidewalks are of double thicknesses, the sub-flooring for each being of two-inch white pine, the top flooring for the roadway of three-inch white oak. and that for the sidewalks of one and a half inch yellow pine, tongued and grooved and dressed on the upper surface. The upper chords of the trusses and the vertical posts are formed of rolled plates and angles, and the lower chords and inclined ties of link bars, with pin connections throughout.

The principal dimensions are as follows:

Span, centre to centre of end lower chord pins.....213 ft. 4 inches.
Height of truss, centre to centre of chord pins..... 21 " 4 "
Number of main panels, ten.
Number of sub-panels, twenty.
Distance between trusses, centre to centre..... 40 " 0 "
Distance centre of truss to centre of handrailing..... 10 " 0 "
Entire width of bridge, centre to centre of handrailing.. 60 " 0 "
Clear span between masonry on the square.....185 " $9\frac{7}{32}$ "
Clear span between masonry on the askew.....209 " 3 "
Angle of askew..... 62° 35′ 47″

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18. *Detail Drawing of 520 feet iron truss of Cincinnati Southern Railway Bridge over Ohio River at Cincinnati. Built by Keystone Bridge Co.*, J. H. LINVILLE, C. E., President. (See Plate XLVII.)

The portion of this bridge constructed by the Keystone Bridge Company, under their contract dated February 24th, 1875, embraced the

BRIDGE OVER THE PENNSYLVANIA RAILROAD AT FORTY-FIRST STREET, PHILADELPHIA, PENNA.

JOSEPH M. WILSON, ENGINEER.

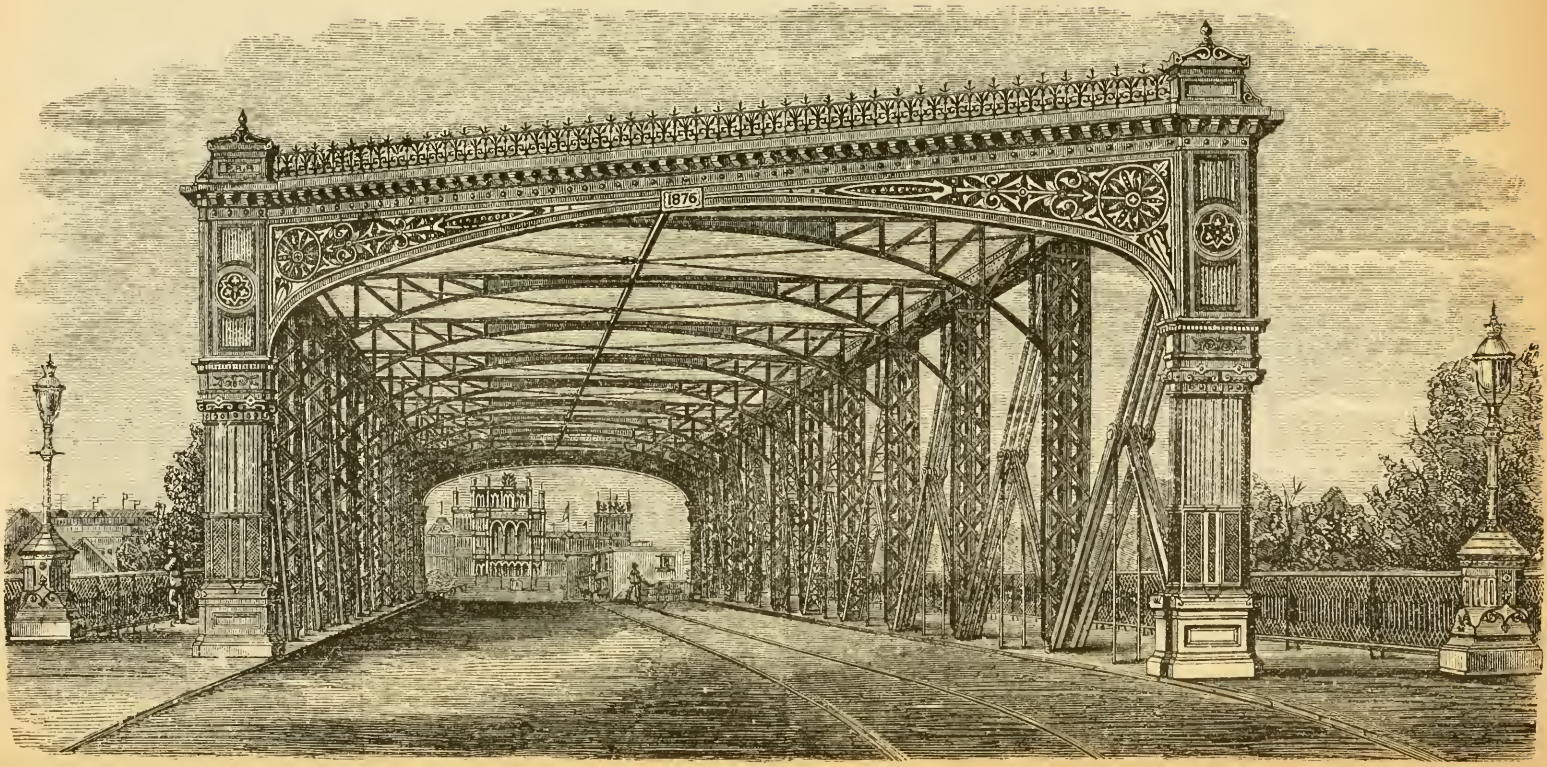

PLATE XLVI.
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Plate XLVII.

southern abutment and piers numbers 1 to 6 inclusive, and the superstructure for the following spans, viz. :

One Deck Span.....110 feet.
One Pivot Span.....370 "
One Channel Span.....519 "
Two through Spans.....300 "

Making a total length of 1 599 feet, measured from centre to centre of piers.

The general data are as follows :

	Span 1.	Span 2.	Span 3.	Span 4.	Span 5.	Total.
Length, centre to centre, piers.....	110′	370′	519′	300′	300′	1 599′
" " " pins.....	108′ 0 25/32″	365′ 4″	515′	295′ 1″	295′ 4″	
Depth, " " chords.....	15′ 6″	36′ 6″	51′ 6″	37′	37′	
Width, " " trusses.....	10′ 0″	15′ 6″	20′ 0″	15′ 10″	15′ 10″	
Weight of Iron..... lbs.	104 400	826 500	2 634 400	657 400	657 400	

Masonry for Spans 1 to 5 inclusive.....12 621 cubic yds.
Concrete..... 500 " "

The contract price was $663 570.00. with a provision for contingencies, which increased the entire cost to about $700 000.

The designs for the superstructure were submitted by J. H. Linville, C. E., President of the Keystone Bridge Company, and embraced his latest improvements. These plans were slightly modified by the engineer of the railway company, the work being constructed under his supervision, and subject to his approval.

The lower chords are placed at an elevation of 43.25 feet above high water and 105.65 above low water.

The trusses of the channel span are trapezoidal, consisting of 20 equal subdivisions or panels, with vertical intermediate posts, and inclined end posts, the tension diagonals reaching two panels, and being inclined at an angle of 45 degrees.

The lower chords have rectangular ends, and are packed closely together, forming a flat bearing on their upper surface for the bases of the posts, and a recessed bearing on under side to receive the suspended floor girders and resist the action of the lower lateral ties.

To give greater width of truss, twin rectangular posts were used, stiffened at the middle of the height by longitudinal struts extending, between posts, from end to end of the trusses. At the intersection of these struts with the posts transverse struts and diagonal ties were introduced to serve as wind bracing, and maintain the lateral stability of the trusses.

Floor girders are 4 lines of stringers, of wrought iron built beams, which support the long wooden ties and guards.

The bridge is designed to sustain, in addition to its dead weight, the following rolling load, at a speed of 30 miles per hour, viz., two locomotives coupled, each weighing 36 tons, on drivers in space of 12 feet, total weight of engine and tender loaded 66 tons, in space of 50 feet, and followed by loaded cars, weighing 20 tons, in 22 feet. An addition of 10 to 30 per cent. is added to the strains produced by the rolling load (considered as static) in the calculation of floor beams, stringers, suspension links, counter rods, and all other parts of the bridge liable to be strained suddenly by the passage of a rapidly moving load.

Wind pressure of 50 pounds per square foot is provided for.

Tensile strains were limited to 10 000 pounds per square inch on best double refined iron. Strain of compression in large rectangular chords to 8 000 pounds per square inch. And on posts the strains were limited to 6 000 pounds per square inch,

The bridge was constructed at the shops of the Keystone Bridge Company, Pittsburgh, and erected on trestling consisting of three tiers of lower scaffolding and two tiers of upper falseworks. It required the labor of 60 men 24½ days to raise the iron work and put it in place preparatory to swinging the trusses clear of the scaffolding.

All the iron used in the structure was tested by specimens. Special forms of joints were tested to breaking to determine their proportions, and all lower chords and suspension bars were tested to 20 000 pounds per square inch.

The channel span was subjected to a test load of seven locomotives coupled and four flat cars—weight, 966 000 pounds. The maximum deflection was $2\frac{3}{32}$ inches.

Model of Point Bridge across the Monongahela River at Pittsburg, Pa. Loaned to the Society by the American Bridge Company.

Point Bridge was designed by Edward Hemberle, Engineer of the American Bridge Company. It consists of tower and chains, with platform suspended therefrom in the same manner as in a regular chain suspension bridge. To this is added a stiffening system above the chains, and rigid posts arranged between chains and platform so as to prevent the roadway from undulating or oscillating independently of the structure above. The stiffening appliances above the chains consist of rigid chords running in straight lines from the top of the tower toward the center of the chain, and connecting thereto by a hinged joint at each end. Between these chords and the chains there is a system of bracing, composed of posts and diagonal tie-rods, all connections being pin-jointed. The chain, being a catenary, or curve of equilibrium, bears all the permanent load of the structure without straining the stiffening trusses. This object was accomplished by erecting the bridge completely

before connecting the ends of the straight top chords to the centre joint. The rods are provided with turn-buckles, and are so adjusted as to be strained under moving loads only.

The total length of the bridge is 1 245 feet from back to back of anchorages, with one middle span of 800 feet between centres of piers, and one independent trussed side span of 145 feet in length at each shore. The roadway rises from both shores toward the centre of the channel, with grades not exceeding 3½ feet in 100—the highest point of the roadway being 83 feet above low water. The saddles upon which the chains rest on top of the towers are 180 feet above low water. The deflection of the chain is 88 feet, which is considerably more than is usual for supension bridges, but the stiffening allows of increasing the deflection and thereby reducing the strains in the chains as well as their weight. The bridge is 34 feet wide from centre to centre of outside railings, and this space is divided into a roadway 21 feet wide and two sidewalks of 6½ feet each.

Photograph showing iron derricks used by the Passaic Rolling Mill Company, of Paterson, New Jersey, in the erection of the New York Elevated Railroad.

These derricks were designed by Mr. Watts Cook, President of the company. The smaller one consists of two trucks, one carrying an iron hoisting frame and the second a hoisting engine; the two trucks are coupled together, and in use their wheels rest on the girders already placed in position; the forward arm of the hoisting frame reaches to the centre of the span to be erected while the rear arm is anchored down; with this derrick a gang of twelve men have erected 210 tons of iron in ten hours. The larger derrick has but one truck, which runs on rollers instead of wheels, the power being placed at the centre of the frame, which is 108 feet long and has a reach of 50 feet.

Large crayon perspective drawing of the East River Suspension Bridge connecting the Cities of New York and Brooklyn. Loaned to the Society by Mr. William Hilderbrand.

Three sections of wire suspension bridge cables, being full-sized models of the cables of the East River, Cincinnati and Niagara Suspension Bridges. Loaned to the Society by John A. Roebling's Sons.

Album of photographs and portfolio of drawings of bridges built and designed by Clarke, Reeves & Co., Phœnixville Bridge Works.

Album of photographs of bridges built by Keystone Bridge Company.

Portfolio of photographs, etc., of bridges designed by Wilson Brothers & Co., of Philadelphia.

HYDRAULICS.

WATER AS APPLIED TO COMMERCIAL INDUSTRIES AND DOMESTIC PURPOSES WITHIN THE UNITED STATES.

Among the earlier immigrants to this country there were many mechanics and artisans, and the small streams in the neighborhood of settlements were soon utilized for the purposes of grist and saw mills, to which later were added tanneries, card and fulling mills. With the organization of the States under one general government, the necessities of means of communication and of exchange of commodities, called attention to the improvements in inland navigation adopted in other countries, and rivers began to be improved by the construction of dams, with supplementary canals around dangerous falls, as early as 1792. From these small beginnings, other canals were projected and carried out through the Northern and Middle States, so that at the inception of railroads, say in 1835, there were in the United States over 3 500 miles of navigable canals, and many miles of slack water navigation. With the introduction and spread of railways, the construction of canals almost entirely ceased, and many already in operation were discontinued, but many of the important ones have been improved, and their carrying facilities increased, and at this time the tonnage of the canals, consisting mostly of grain, coal, lumber, and heavy materials, is an important factor in our internal commerce. The Erie Canal, built by the State of New York, to connect the waters of Lake Erie with those of the Hudson River, com-

pleted in 1825, did much to develop the resources of the State, and to establish the City of New York as the largest port of the United States. Its enlargement was commenced about 1840, and completed in 1862. Its present depth of water is 7 feet, and maximum capacity of boats 240 tons. Its cost to 1876 was $49 000 000, and the tonnage for the year 1877 was 857 305 563 tons, carried one mile, whilst that of the New York Central Railroad, during same year, was 1 619 948 685 tons one mile. The length of the main Erie Canal is 352 miles, and with connections and feeders, 907 miles; movement on all those canals, about 5 000 000 tons. In Pennsylvania, the canals are used largely for the transport of coal. The Lehigh Coal and Navigation Company transported by their canals, in 1876, about 1 000 000 tons; the Delaware and Hudson Canal, 1 300 000 tons; the Schuylkill and Susquehanna about the same, and the Pennsylvania Canals about 900 000 tons. The Chesapeake and Ohio canal carries on a large coal trade between the Cumberland coal region and Washington and Alexandria.

The Morris Canal, in New Jersey, connecting the Delaware River with New York Harbor, with feeders extending into the coal region, still continues to do a considerable coal trade. On this canal the experiment of inclined planes was first tried and they are still in successful use. Along the Eastern coast, by the connection of the sloop canal of Albemarle Sound with Chesapeake Bay, Chesapeake Bay with Delaware Bay, and Delaware Bay with the Raritan River, there is inland navigation from Albemarle Sound to New York City.

In Illinois, the Illinois and Michigan Canal, from Chicago to La Salle, opens the navigation between the Great Lakes and the Mississippi River, and carried in 1873, eight million bushels of grain, and 50 million feet of lumber, besides large freights in shingles and laths. There is a short canal at Sault St. Mary's, connecting the navigation of Lake Superior with that of the other Great Lakes.

As said above, at a very early date, the small streams in the neighborhood of settlements, were utilized for saw and grist mills and the like, but it was not till the war of 1812–15, when an embargo was laid upon our commerce, that capital began to be used largely in industrial works, first by individuals or small firms, developing the old water powers, for the driving of cotton and woollen mills; thence still further utilizing the smaller streams, like the Charles, the Blackstone and the Passaic. But with the increase in demand for goods, and profit in their manufacture,

the necessity for large mills was recognized, and as large capital was not in single hands, corporations of combined capital were organized to develop large water powers for more extensive industries. It was found in 1821, that the old canal of the Locks and Canals on the Merrimack could be made readily available, and the whole water of the Merrimack, with a fall of 30 feet, could be made use of, and this power, it was supposed, would supply an almost indefinite demand. The Locks and Canal Company became the owners of nearly all the land in the neighborhood of the canal within the limits of the present City of Lowell, and sold land with mill powers, a mill power being equivalent to 25 cubic feet per second on a 30 foot fall. At the present time they are running up to about 200 mill powers. With the success of Lowell, water companies on the same basis were organized throughout the different States, water power and land belonging to these corporations and the mills to others. Manchester and Lawrence were built on the Merrimack; Lewiston on the Androscoggin; Biddeford on the Saco; Bellows Falls, Turners Falls, Holyoke and Windsor Locks on the Connecticut; Ansonia on the Naugatuck; Derby on the Housatonic; Cohoes on the Mohawk; Rochester on the Genessee; Paterson and Dundee on the Passaic; Trenton on the Delaware; Manayunk on the Schuylkill, and many others.

At the first the science of hydraulics was but little understood and capital not abundant; the dams were mostly of timber, and the canals of but little capacity. Now most of the dams are substantial structures, and canals of such section that the velocity of the flow is often less than 2 feet per second.

The earlier water wheels were almost invariably over-shot, pitch-back, or breast wheels. Many were of large dimensions, and well constructed, with cast iron shafts. The percentage of useful effect was sometimes as high as 80 per cent., but the average was considerably below 70 per cent.

But with the introduction of the Fourneyron wheel in France, the attention of engineers here was called to it, and Mr. Edward Morris constructed and put into operation one near Philadelphia, which indicated 75 per cent. of useful effect. In 1844 Mr. U. A. Boyden constructed one for the Appleton Company at Lowell which gave 78 per cent., and in 1846 two for the same company which gave 88 per cent., and many other wheels with equally good results.

The quantity of water was invariably determined by the flow over a wier, and the mechanical effect by a Prony dynamometer, and as

the compensation of Mr. Boyden was dependent on the percentage of useful effect obtained, it became very important that the formula for the flow over wiers should be rigorously determined. And as the formula thus far was derived from discharges of water and breadth of weir much less than were necessary for comparison with the discharge of large turbines, Mr. James B. Francis, at the expense of the Locks and Canals Company of Lowell, undertook a long course of trials, which have been published under the title of "Lowell Hydraulic Experiments," and as the most satisfactory form of formula Mr. Francis adopted that recommended by Mr. Boyden, in which the correction of length of wier for end contractions is a factor of the depth on the wier, and in taking the heights of water above the wier he adopted Mr. Boyden's hook gauge as the most accurate. The formulæ obtained by Mr. Francis are now the standard throughout this country, and are adopted wherever a wheel is to be tested.

The success of Mr. Boyden's wheels were due to their design and to the accuracy of their mechanical details and finish, the later wheels having bronze buckets to the wheels and guides. They were as expensive as steam engines of the same power, but they still endure after years of work.

Wheels of this form were more adapted to mills than the old breast or over-shot wheels, occupying a great deal less space, running at a more suitable speed, and more easily regulated, and when it was demonstrated that the percentage of effect was greater, the manufacture of reacting wheels spread throughout the country. Jonval wheels were built at Philadelphia, Patterson, Cohoes, and various forms were experimented on elsewhere to secure high percentage of useful effect, with cheapness of construction. At the first it was not possible to exceed that already obtained by Mr. Boyden, but it was thought possible that wheels of cheap construction and with a very fair percentage of effect could be made. This has been done; the forms now most generally adopted are wheels with a central and downward discharge; and makers, before issuing circulars to the public, either test their wheels at their works or have them tested by weir discharge and Prony dynamometer, and their guarantee of power is based generally on a standard of 80 per cent. of useful effect.

Water for manufacturing purposes is estimated by cubic feet of discharge multiplied by feet of fall. In California, where the water is used

for washing earths and ores, water is sold by the inch, that being usually the quantity which escapes through an orifice one inch square with the water six inches deep above the top of the orifice ; as measured an inch of water is considered equal to $2\frac{1}{3}$ cubic feet per minute. The mining ditches of the State (1871) carry at least 100 000 inches, or about 2 500 000 000 gallons in 24 hours. This water is carried in open canals, in wooden frames and iron pipes. The latter are used now invariably in crossing deep ravines, and the necessities of the positions have led to the adoption of heroic engineering precedents in regard to the thickness of metal, coupled with diameter of pipe. Thus the Swartsville pipe, 16 inches diameter, under 180 feet pressure, of No. 18 sheet iron, was laid in 1861, not painted inside but painted on the out. San Juan, 30 inches diameter. Nos. 12 and 14 iron, 55 feet head, coated inside and out, laid in 1861. Chinese camp, Nos. 12, 14, 16 and 18 iron, maximum head 800 feet, was laid in 1868. The pipes are double riveted on the longitudinal seams, put together like stove pipes and riveted, and coated with coal tar.

Most of the water thus distributed is used, as is said, "to hydraulic," that is, to wash banks of auriferous earth by throwing a stream of water upon them through a hose and pipe. Hydraulic claims are usually in hills. The water is brought to the bottom of the hill by an iron pipe or by a hose. The hose is of heavy duck, and from 4 to 10 inches diameter, sometimes surrounded by iron rings 2 inches wide and 3 inches apart, connected by 4 ropes. It is important to preserve as great a head as possible, with flexibility of hose. The nozzles are like those of fire engine hose, sometimes as large as 8 inches diameter, with a discharge of 300 to 800 inches of water. The miners usually turn the stream upon the banks near the bottom until a large mass of earth tumbles down. They then wash all this away into the sluice, and then cut the bank again at the bottom. The water usually costs 10 cents per inch per day, and dirt in this way has been in some places excavated at a profit when it contained one cent's worth of gold in a cubic foot. The same hydraulic process has been used for excavation merely.

Besides water for washing earths, canals are used in California for irrigation, and in 1876 there were 915 irrigating ditches supplying water to 90 344 acres.

City Supply.

Few of even the medium sized cities of the United States are without some system of water supply and distribution. Philadelphia was first in

the inception of such works, which was effected by the construction of a dam across the Schuylkill, with breast wheels and pumps raising water into a reservoir and then distributing it through the city. The breast wheels have given way to more efficient reactors, and the supply has been supplemented by steam pumping engines, both on the Schuylkill and on the Delaware.

New York is supplied by gravitation, bringing the water from the Croton through some 38 miles of brick aqueduct and some iron conduit. The iron conduit or pipe lines across Harlem and Manhattan Valley have been increased in capacity. A large receiving reservoir of 1 000 000 000 gallons capacity, and two large catch basins on the Croton river have been constructed since the completion of the works; together with two pumping engines, of 10 000 000 gallons per 24 hours' capacity, for the supply of the highest parts of the city. The daily supply is now about 90 000 000 gallons.

Boston has also a gravitation supply from Lake Cochituate, but has lately constructed an entirely new aqueduct, taking all the upper waters of the Sudbury river. By the annexation of Charlestown, the pumping works of Mystic pond have been added. The total daily supply is now about 30 000 000 gallons.

The supply of Washington is also by gravitation from the Potomac, and is the largest in quantity in proportion to the number of its inhabitants.

But, in general, most of the cities are supplied by steam pumping engines, of which the exhibit of St. Louis is a very fine type, and, together with those of Messrs. Leavitt and Worthington, represent our best practice.

Usually with all city water works there are reservoirs. In some cases the pumping is directly into the main, without reservoirs. In Sandusky the engineer, Mr. J. D. Cooke, has introduced, as an economical construction, under the conditions of position, a very large stand pipe, serving, in a measure, as a reservoir, with a small central pipe which will be useful in putting an extra head on the mains in case of fires. The large pipe, 25 feet inner diameter, 180 feet high; the central pipe 8 feet diameter, 230 feet high. The large pipe is of steel plate, having a reliable tensile strength of 70 000 lbs. The plates build 4 feet per course, each course being composed of 6 plates, 1st and 2d course $\frac{5}{8}''$ thick, 3 rows of $1\frac{1}{8}''$ steel rivets, then reducing by each two courses the thickness of the

plates by $\frac{1}{32}''$; the 43d and 45th course, inclusive, is $\frac{3}{16}''$ plates, $\frac{1}{2}''$ rivets, double. The rivets were changed from triple to double rows at 24th course. The top is finished with galvanized iron cornice; the whole thoroughly painted, inside and out. Influent and effluent pipes pass into and through the shell of large pipe near the bottom. Either pipe can be used independently of the other; valves so arranged that the engineer can change to either pipe without leaving the engine house.

The types of pumping engines used at the different works are extremely varied. The drawings sent to the exposition are very favorable specimens of American practice. The pumping engines of Mr. Leavitt are compound engines, with the steam cylinders inclined to each other, and at their bases are close to each other as possible. The connections are with opposite ends of the beam, and the channels between the cylinders are short as possible. The fly-wheel connection is with one end of the beam and the pump connection with the other. This type of engine, of which there are three in operation—one at Lynn and two at Lawrence—both in their tests by experts and every day running, have given the best percentage of effect of any in the country.

The Worthington engine is the legitimate growth from the donkey engine which was first introduced for the feed of boilers by Messrs Worthington & Baker. In its present form, as a pumping engine for water supply to towns, it is a compound horizontal engine, with two sets of high and low pressure cylinders, and its distinctive character is, that the steam valves of one set of cylinders are moved by the piston rods of the other. There are, probably, more of these engines than of any other one type; they are well adapted to a very fair percentage of duty, and they are economical, in first cost including foundations, and repair in working. They are of medium size, the largest in operation having a capacity of 8 000 000 gallons per 24 hours.

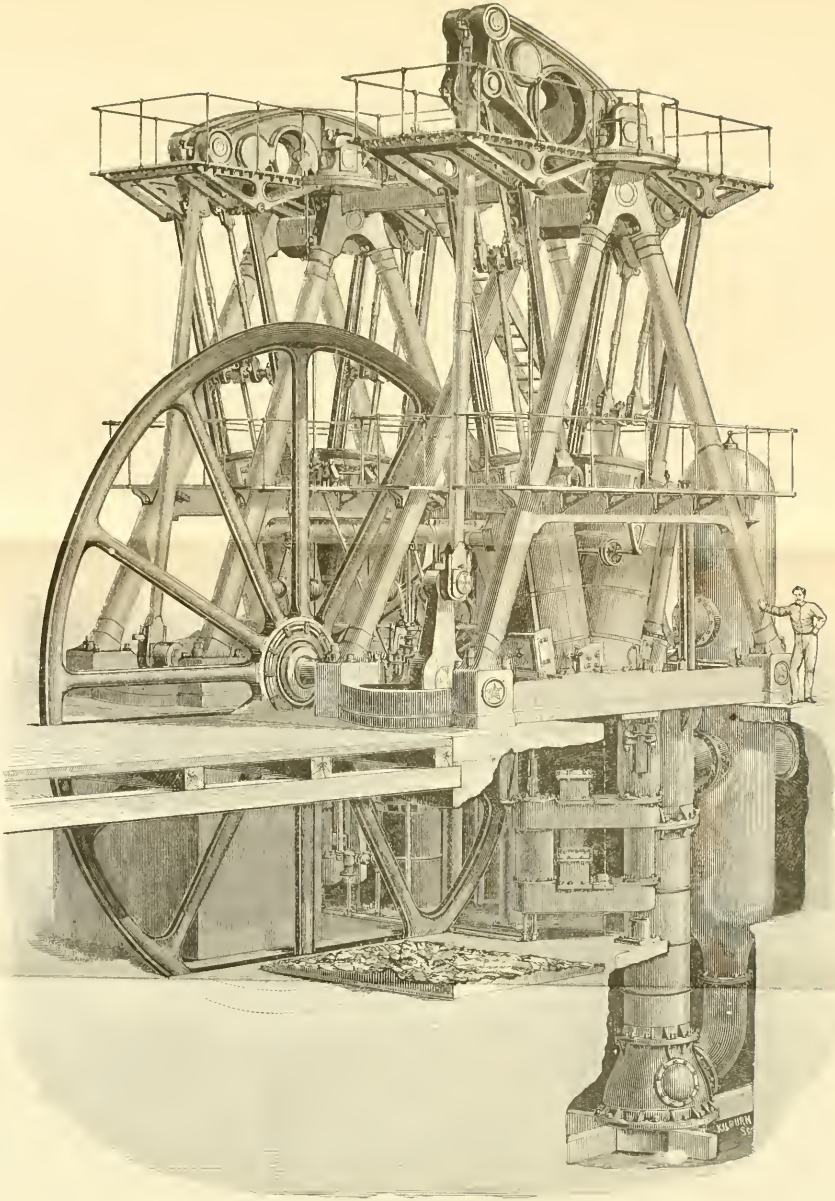
The St. Louis engines are of the largest capacity of any in this country. Engines Nos. 1 and 2, high service, are simple beam engines, with the pumps beneath the steam cylinders and directly connected; the crank connection is with the opposite extremity of the beam. The pump is of a type first introduced by Mr. Wm. Wright at the Brooklyn Water Works. The pump cylinder being enclosed in an annular cylinder, acting as a supplementary pipe to the pump, and affording more ample passage for the water than could be secured through the pump bucket alone. Engine No. 3, High Service, is a coupled compound beam engine, with

the two steam cylinders set close to each other and attached to the same side of the beam. The pump and crank connections are with the opposite ends of the beams. At the low service the water is pumped from the river into subsiding basins, and thence, by the high service, into the mains and reservoir. Engines Nos. 1 and 2, low service, are Bull engines, that can be run coupled. No. 3 is a beam engine, with two plunger pumps, one beneath the steam cylinder and directly connected therewith. On the piston-rod there is a connection with the extremity of a beam, at whose other extremity there is another pump and a flywheel connection. This pumping engine has two distinct condensers, the first in connection with a regular air pump on the main piston-rod, which is supplied by injection from the clear water main of the city, and the condensed water is used entirely for the supply of the boilers, at from 140° to 150°. The other is a syphon condenser supplied from the pump chamber with river water and the condensation is effected by means of a sprinkler. All this condensed water is returned to the river.

Of late, all the pumping engines of a capacity of 5 000 000 gallons per 24 hours, and above, have been fitted with compound engines. The St. Louis engine, No. 3, may represent the type of Milwaukee, Chicago and Lowell. In the Yonkers engine Mr. Wright has placed the cylinders vertically and at opposite ends of the beam. There are a great many Bull and Cornish engines used for the supply of towns and drainage of mines, and the English pump of Drury has been introduced into California. The pumps of the Holly system are inclined cylinders, with directly connected pumps beneath and a connection above with a crank on a fly-wheel shaft, usually with four cylinders, two at each end of the shaft, and arrangements to work either simply or compound.

The forms of boilers are, perhaps, more varied than that of the engines. The most usual types are the *horizontal tubular*, fired underneath and returning through the tubes; the *drop flue*, horizontal with large flues to a back connection, then returning through smaller flues or tubes to a front connection, thence out at the bottom and back to the chimney; and the *Cornish*.

PLATE XLVIII.



PUMPING ENGINE AT LAWRENCE, MASS

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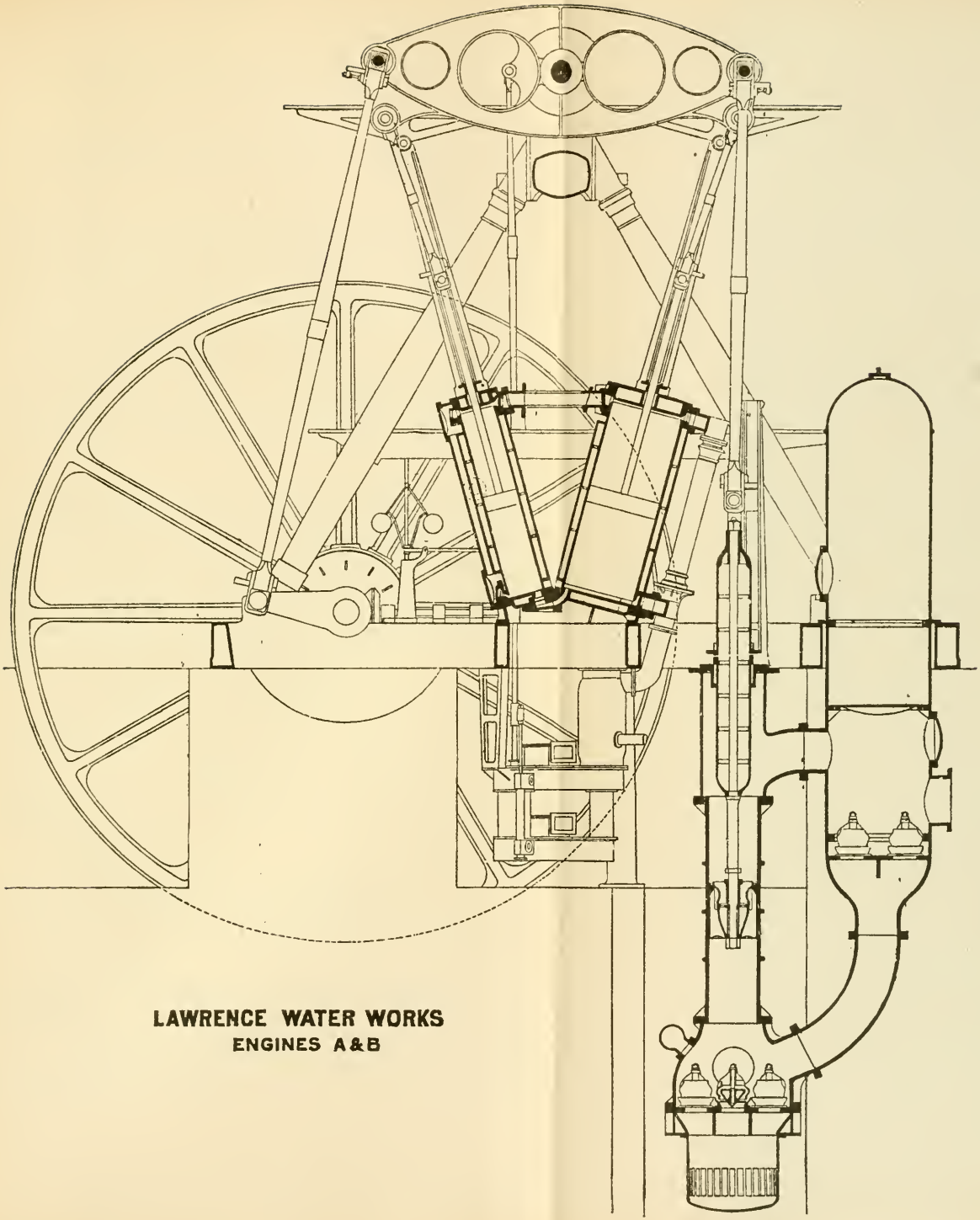

LAWRENCE WATER WORKS
ENGINES A&B

SUBJECTS EXHIBITED.

19. *Photographs of Pumping Engine at Lawrence, with Indicator Cards, &c. Designed by* E. D. Leavitt, Jr., C. E. (See Plates XLVIII, XLIX.)

The engines are two, with a single fly-wheel between them. The two steam cylinders, both steam jacketed, are placed beneath the main centre of a working beam, and inclined outwardly at the top to connect with opposite ends of the beam, reducing thereby the length of the steam passage between the cylinders, equalizing the stroke, and economizing space, with a strong and compact frame.

The cylinder valves are all gridiron valves, with large area of opening and small movement. The steam valves to the high-pressure cylinders are operated by cams controlled by governors, one to each engine. When running coupled, the cam of one engine is set and the other controlled by its governor.

Air-pump double-acting; feed-pump connected with air-pump rod. The pumps are of the Thames Ditton variety, bucket and plunger, but with a supplementary delivery pipe. There are seven double-beat valves for suction, and four in the supplementary pipe, and the bucket valve for the delivery. Attached to the lower valve chamber there is a small spherical chamber with an air-cock at the top, by which air may be introduced into the pump, which is found, at particular stages of water in the well, to contribute to ease in the working of the pump.

TABLE OF DIMENSIONS.

Diameter of high-pressure cylinders	18	inches.
" low " "	38	"
" high " " rods	$3\frac{1}{2}$	"
" low " " "	4	"
" air-pumps	15	"
" pump-barrel	$26\frac{1}{8}$	"
" " plunger	$18\frac{1}{2}$	"
" " " rod	$4\frac{1}{2}$	"
" bottom and supplementary valves outside lower seat	$15\frac{3}{4}$	"
" " " " inside upper "	$12\frac{1}{2}$	"
" bucket-valves outside lower seat	22	"
" " inside " "	15	"
" air-chamber	54	"
" fly-wheel	30	feet.
Length of stroke of steam and water pistons	8	"
" " air-pump	28	inches.
Distances between End Centres of Beam	$16\frac{1}{2}$	feet.
Lead on steam-valves	0	

Lead on high-pressure exhaust valves	$\frac{1}{16}$ inch.
" low " inlet	$\frac{1}{16}$ "
" " " exhaust bottom	$3\frac{5}{16}$ "
" " " " top	$4\frac{9}{16}$ "
All measured on stroke of pistons.	
Cushion on high-pressure top exhaust	$14\frac{1}{4}$ "
" " bottom "	$14\frac{3}{4}$ "
" low-pressure top "	$4\frac{1}{2}$ "
" " bottom "	$8\frac{1}{4}$ "

VOLUME OF CLEARANCE AND PORT SPACE:

High-pressure top	.0256	of cylinder capacity.
" " bottom	.0231	" "
Low " top	.0154	" "
" " bottom	.0182	" "
Connecting pipe between cylinders	.0992 H. P.	" "

Weight of fly-wheel	35 900 lbs.
" walking-beam, including pins and counter-balance	25 700 "
" high pressure piston and connections	2 575 "
" low " " " "	4 175 "
" air-pump " " "	1 800 "
" pump, plunger bucket	7 200 "
" main connections, beam to crank	3 800 "

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20. *Photographs of Pumping Engines of St. Louis Water Works.*

The photographs exhibited of the engines of the St. Louis Water Works are three in number, representing three of the four types of pumping engines employed at these works. The fourth type is not represented.

The first type is No. 1, low service engine. There are two engines precisely of this type. They are Cornish engines, of the kind introduced by Capt. Bull. The principal dimensions are as follows: Diameter of steam cylinder 56″, stroke 144″, speed $8\frac{1}{2}$ to 9 strokes per minute, air-pump 28″ diameter, stroke 72″. Main pump 56″×144″, being the same as the steam cylinder. The pump is a plunger pump. The lift of water is from 15 to 50 feet, according to the stage of water in the Mississippi river, from which the supply is taken.

The capacity of each pump is 17 000 000 United States gallons in 24 hours. These engines were built by the Knapp Fort Pitt Foundry Co. of Pittsburgh, Pennsylvania, in 1870. The pump valves and seats are of composition, "Government standard," viz.: copper, 85 per cent., tin, 10 per cent., spelter, 5 per cent. The valves are "Cornish Equilibrium," arranged in two tiers of twelve valves each. Diameter of lower valve seat 17″, of upper valve seat 15″, lift of valve $1\frac{1}{4}$″. These two engines were erected by the parties above mentioned, in accordance with a proposal made by them on February 15, 1868, to construct the two

engines for $89 800. Steam for these engines is supplied by two internally fired fixed boilers, two for each engine. They have each 650 square feet heating surface, and 27½ square feet of grate surface. The boilers are 7 feet diameter and 30 feet long, the flues 30″ diameter, the full length.

The second type of engine is Engine No. 3, low service, a crank and fly wheel engine with Wright's valve gear, built by Gerard B. Allen & Co. of St. Louis, 1874. The contract was awarded in accordance with a proposal made on November 11, 1872, to construct the engine for $118,500. The principal dimensions of the engine are as follows: Steam cylinder 60″×84″ without steam-jacket, air pump (single acting) 26″×84″. Two main pumps 50″×84″ each. The pump valves are of leather and hinged, placed in the central chamber in two tiers. The capacity was intended to be 1 000 000 United States gallons per hour. The action of the valve gear is excellent. The lift of water is that already stated for Nos. 1 and 2 engine, viz.: from 15 to 50 feet.

The third type of engine is Nos. 1 and 2, high service engines, which are alike. No photograph of this type is exhibited. The engines are very similar to No. 3 Ridgewood engine at the Brooklyn Water Works, described in Mr. Kirkwood's book, "The Brooklyn Water Works." The engine is a crank and fly wheel engine with a beam. The principal dimensions are, steam cylinder 85″×120″ (jacketed). Air pump 36″×60″, double acting. The main pump is directly under the steam cylinder, and worked by an extension of the piston rod. The pump is a bucket and plunger pump of the kind known as "Thames Ditton." Diameter of plunger 36½″, of bucket 51½″, stroke 120″. The pumps receive water through a 50″ pipe, and discharge through a 36″ main. Air chambers of ample capacity are located near the pumps. The pump valves are "Cornish Equilibrium." There are 11 suction and 10 discharge valves. Diameter of lower seats 16″, of upper 13¾″, lift of valves 1⅛″. There is also a large bucket valve of the same kind. The lower seat is 40½″, the upper 34½″ diameter, the lift 4″. The steam valve gear is of the kind known as "Sickel's," and the cut-off is worked from the parallel motion. Diameter of fly-wheel 26 feet, weight 30 tons. The head against which these pumps work is about is about 200′, and the capacity 17 000 000 United States gallons in 24 hours. These engines were contracted for at $188 800, in accordance with proposal made February 15, 1868, by the Knapp Fort Pitt Foundry Co. of Pittsburgh, Pennsylvania, and were finished in 1870. They have been very satisfactory. The consumption of steam is 25 pounds per indicated horse power per hour, the rate of expansion from 3 to 4, the number of revolutions per minute 11½, though they have been run on a trial at 14½. Steam is usually furnished to each engine by six boilers, each with internal fire place and return flues. The grate surface is 25 square feet, the heating surface 500 square feet to each boiler. The steam pressure is 40 pounds per square inch.

The fourth type of engine is No. 3, high service engine, of which a photograph is exhibited. This engine works against the same head as the other high service engines, but has a capacity of 1 000 000 gallons per hour. The engine is a double beam compound engine. There are two high pressure steam cylinders unjacketted 50″×87″. The low pressure cylinders 80″×138¼″, the cranks are set at right angles on a shaft which carries a fly-wheel 32′ diameter, weight 35 tons. The air-pumps are double acting, each 23″×54″. The main pumps are each of the "Thames Ditton" kind, plungers 32″, buckets 45¼″ diameter, and 100″ stroke. The pump valves are "Cornish Equilibrium," and the steam valves are driven by spur gearing on the shaft. The action of the pumps is exceedingly smooth. The contract for these engines was awarded to the Hartford Foundry & Machine Co., on March 19, 1873, for $280 000, and was finished in 1874.

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21. *Photograph of Stand Pipe of Sandusky Water Works. Designed by* J. D. Cooke, M. E.

This stand pipe is described in the general article.

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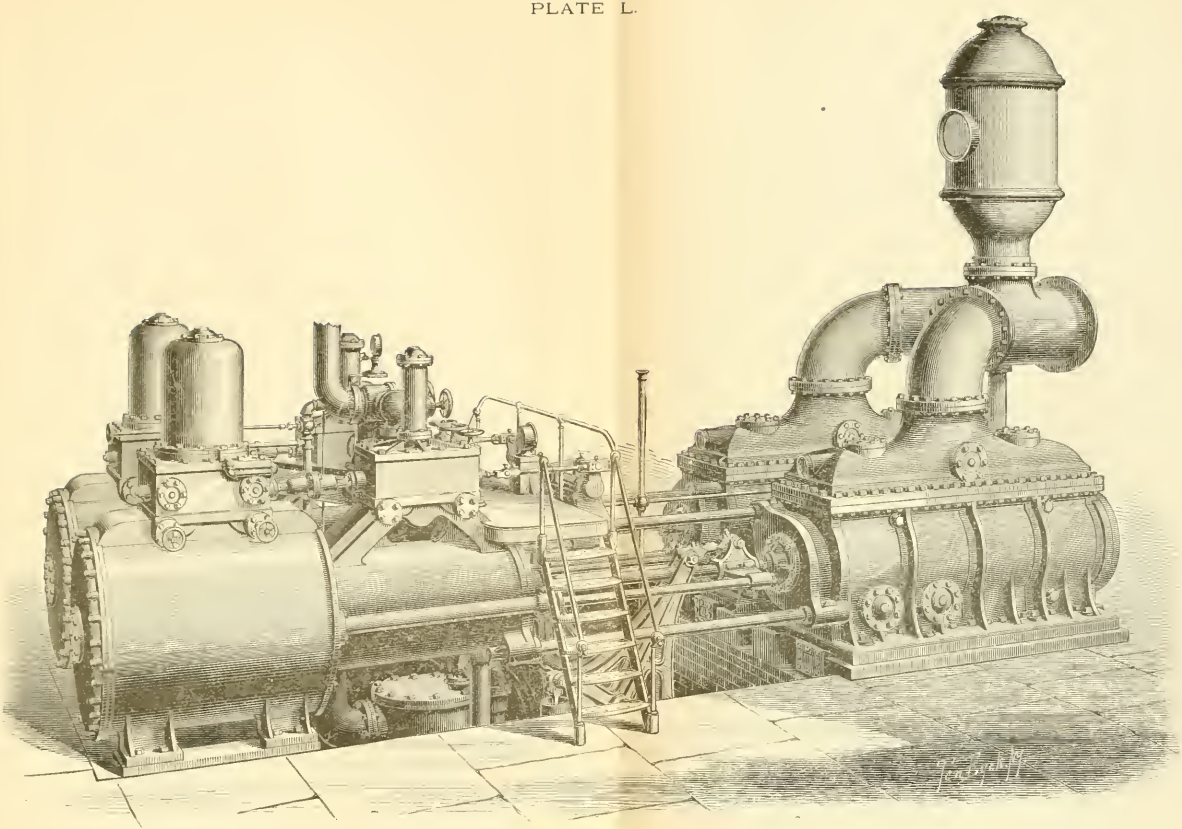
22. *Photographs of Worthington's Duplex Pumping Engines. Designed by* Henry R. Worthington, M. E. (See Plate L.)

The pumps are in pairs, horizontal and double-acting, arranged side by side on the same frame, each operated directly by a compound engine with steam jacketed cylinders. The smaller steam cylinder is attached to the front head of the larger, and has a central piston rod connecting with pump rod through a cross-head, and two piston rods from the larger cylinder pass outside the smaller and connect with the cross-head. There are two single-acting air pumps, which are operated from the ends of a horizontal beam, with vertical lever attached, receiving motion from one main cross-head. The main valves are plain slides operating over double cylinder ports.

The valves for both cylinders of each engine are arranged on the same stem by raising the chest of the smaller, and each valve is provided with a balancing piston. The valves of one engine are operated by bell cranks directly from the reciprocating parts of the other, and no rotative movements, with accompanying details, are required. Double cylinder ports are provided—the outer ones receive steam past the ends of the valves, and admit same to the cylinder in the usual way; the inner ones communicate with the exhaust cavity of the valve only, and enter the cylinder at such distances from the ends that when steam is exhausting through one of the ports the main piston will run over and close it, and cushion upon the vapor thereby inclosed, the outer port being at the time shut off by the main valve. Valves are provided to put the two cylinder

PLATE L.



WORTHINGTON DUPLEX PUMPING ENGINE.

ports at each end in communication to regulate the extent of cushioning. The pump valves consist of rubber disks arranged in chambers above and below the plungers. Each plunger runs, without packing, in a long grooved ring in a central diaphragm. In operation, one engine, while in full action, moves the valves of the other, when the pistons of the latter gradually begin to move, and finally attain full velocity, as those of the first are checked by the steam cushions and gradually come to rest, the pump valves meantime seating quietly.

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23. *Photographs of Holyoke Dam and Canal.*

The dam across the Connecticut, at South Hadley Falls, was constructed for the supply of water-power to the proposed town of Holyoke, which, since its construction, has developed into a large manufacturing city. The dam, as originally constructed, was 1 017 feet between abutments, with an average height of 30 feet, with a base of 80 feet. It was constructed of timber crib-work, loaded with stone for about one-third of its height. The foot of each rafter is bolted to the ledge underlying the whole dam, and all timbers at their intersections are tree-nailed together with 2-inch white oak treenails. The inclined plank face is loaded with gravel, and the joint at the ledge secured with concrete, The base tiers of ranging timber were 15x15 inches, other timbers were 12x12 inches. The rafters are placed vertically over each other in bents, 6 feet between centres. The planking was of hemlock, 6 inches thick, with oak cross-planking at crest, of 4 inches thick at bottom and 8 inches at top. The crest was plated with ¼-inch iron, 5 feet wide. During the construction, the dam was first planked about 30 feet on the incline. A space was then left about 16 feet deep on line of incline, and of length sufficient to vent the flow of the stream. This aperture was closed by a plank flap, as soon as the dam was ready for the filling of the reservoir. The highest freshet has given over 12 feet depth over the crest. By the action of the water, flowing over the crest, the ledge beneath, after a few years, began to be worn and cut out, to the manifest insecurity of the work; there was, therefore, a roll made of similar construction, to that of the main dam, that is loaded crib work and plank face, which gives a discharge at a distance from the structure, and secured its stability. The water power supplied by this dam is perhaps the largest in the United States, utilizing the whole water power of the Connecticut River, with a fall of about 60 feet.

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24. *Photograph and Drawing of Dam across the Mohawk at Cohoes. Designed by* W. E. Worthen, C. E.

The Cohoes dam across the Mohawk is a stone roll to an old crib dam, which had become very leaky and worn, and which, by its over-

fall, had worn deeply into the ledge of slate stone on which it was constructed. The old dam was left as a sort of coffer-dam for the construction of the new dam, and for a protection to it from the shocks of ice. The exterior of the dam was rock faced ashlar, below, and the cap stones were in single lengths of 10 feet, and not less than 2 feet wide by 15 inches thick. They were dowelled together by 2 galvanized wrought iron dowells. The hearting of the work was of small stone, such as could be readily laid by one man; the whole work was laid very carefully and full in cement mortar. The cap stones were bedded in cement, and joints filled to within 6 inches of top, which was then run full of sulphur. The length of the dam is 1,380 feet, with an average depth of 12 feet below crest of dam. In the construction of the dam the leak of the old dam was stopped as far as possible, by a sheet piling attached to the face of the old dam, and another sheet piling parallel with it, and 18 to 20 inches distant, the joints of this last with the ledge were made tight by sausages, or long bags, about 6 inches diameter, filled with dry sand and cement, forced down along the line of ledge and the spaces between the pilings were divided from time to time by cross-pilings, which made a series of boxes of such sizes as could be readily filled at once by batches of concrete. After the setting of the concrete, all pilings except on face of old dam, were removed, and the spaces filled in with grout, and the concrete became a part of the dam, The work was begun July 14th, 1865, and on October 20th of the same year, it was complete, with the exception of 20 feet of coping. The dam at Cohoes, though of insignificant height, utilizes a fall of about 130 feet, and a minimum flow of about 1 000 cubic feet per second.

INTERNAL NAVIGATION.

The United States, early in its history, was noted for its clipper ships, which successfully competed for an important share of the commerce of the world, and as the population rapidly increased advantage was taken of the numerous great bays, rivers and lakes to extend internal navigation in all directions. In due time important lakes and streams were connected by canals, several of considerable magnitude, though small in comparison with the natural water courses thereby united. The demands incident to the rapid development of the country and the individual freedom of thought and action stimulated enterprise and invention, and the means available were quickly utilized to overcome difficulties and accomplish the ends desired.

Under such circumstances steam navigation was developed. Fitch in 1786 showed it to be practicable; Fulton in 1806 put it in such shape that its great value was demonstrated and success assured. The ocean was crossed by steam for the first time by the American steamer *Savannah*, in the year 1819, and the Collins steamers, brought out about the year 1850, were the first in which the heavy head gear used on sailing vessels was dispensed with, reducing the pitching moments, and indicating the general characteristics of modern ocean steamers.

The steamers used in the internal navigation of different parts of the United States are very different in construction and appearance, being specially adapted for the several locations and the duties to be per-

formed. In the sheltered bays and connecting rivers on the coast, side-wheel steamers are generally employed with large, sharp hulls of light draft and little freeboard. The freight is in general stored on the main deck, and passengers are accommodated in cabins and state-rooms above. The main deck is made much wider than the hull, extending to the outside of the paddle wheels, the overhanging portions being called the guards. The cabins are sometimes extended several stories in height and furnished and fitted with all the comforts and luxuries of hotels and dwellings. The hulls are stiffened longitudinally at each side by an arched truss (hog frame), or centrally by a series of king-posts and diagonals, extending from stem to stern. Each boat is in general propelled by the typical American beam engine with skeleton trussed beam supported by a wooden gallows frame. This form gives ample length of connections, and the necessary flexibility and distribution of strain and weight to permit maximum power to be used continuously in a light hull. The single engine is so narrow that, when enclosed, broad passages are left on each side to connect the forward and after cabins and compartments. In smaller boats, a single boiler is placed below decks. In large, shallow steamers, like those used on the Hudson River, the boilers are placed on the guards. In steamers admitting greater draught, like those used on Long Island Sound, the boilers are placed either on the guards or in the hold. Blowers are generally used to hasten combustion or to permit the use of anthracite pea coal. Some of the larger steamers of later construction have sufficient boiler power with natural draft. Boats making short trips on bays connected with the sea, carry fresh water in tanks for use in the boiler. Those making longer runs, often have surface condensers.

Steamers of this kind are adapted for use on routes along the sea coast and up navigable rivers by simply increasing the depth of hold, and sometimes dispensing with the guards, the freight being stowed below the main deck. The upper cabins are modified according to the average exposure during the sea voyage. Light draft propellers of similar construction are also used on this duty. Propellers are principally used on the great lakes, some being of large size; the draft, however, is restricted to about 14 feet, to pass the flats at Lake St. Clair. Propellers of this kind are used to tow one to four or more barges or schooners loaded with freight.

On the Mississippi river and its network of connecting rivers and

bayous, the steamers are of very peculiar construction. The fluctuations in the depth of water on the bars require very light draft, measured, for many streams, by inches, instead of feet. The hulls are shallow with flat bottoms, the ends sharpened more or less, but generally shaped to throw the water beneath. The main deck receives the machinery and freight, and supported by posts at a considerable distance above it are a series of cabins, reducing in size as they rise, till the "Texas" and pilot house tower over all, just behind two high smoke pipes, from which, when in use, black smoke, and sometimes flame, belch forth; the general appearance, together with the noise of the exhaust steam from the high-pressure engines, makes a lasting impression on the memory. The machinery consists of two horizontal engines, connected one to each side-wheel, or each to a crank at each side of a stern-wheel. The steam cylinders are long and of comparatively small diameter; the bed-plates are wood; the connecting rods or pitmans, of wood strapped with iron; the whole stretched out to distribute the weight as much as possible, and yet located at the sides, so as to be out of the way. The independent arrangement of the two engines enables the pilot to manœuver the boat by the wheels, even more than by the rudder. The steam pressure carried is usually about 150 pounds per square inch. The steam cylinders are fitted with single poppet valves and steam is cut off by a cam, at about half stroke. The feed water is heated by the exhaust steam. The boilers are cylindrical, set in brick work; they are externally fired, and the products of combustion return through two flues in each. Yet these apparently crude constructions have, by years of experience, been found best adapted for navigation in the shallow western rivers containing much sediment. Tubular boilers could not be made to stand, and iron framing or more condensed machinery would strain the boat or increase the dead weight and draft of water.

The cabins of passenger boats are well fitted up and are airy and comfortable, and the steamers do continuous satisfactory work in locations where it would be impossible to operate craft of more elaborate design. Some boats, of from 1 200 to 2 400 tons, "stern-wheelers," run between Cincinnati and St. Louis and New Orleans exclusively as freight boats.

Tow boats, which are all of the stern-wheel class, are 160 to 240 feet long, 30 to 40 feet beam, and draw 3½ to 8 feet water. They carry only fuel, and are provided with powerful machinery. They are largely used

in transporting coal from Pittsburgh, &c., to New Orleans in barges carrying from 480 to 900 tons. These barges are *pushed* in front of the tow-boat. The *Ajax*, in this manner, took 22 500 tons from Louisville to New Orleans. The cost of transportation is 80 cents per ton from Pittsburgh to New Orleans, 2 000 miles, or $\frac{4}{100}$ of a cent. per ton per mile. Grain and other merchandise is also carried in the same way.

Steam is used regularly on the large canals, such as those connecting the Chesapeake and Delaware bays and the seaboard, the vessels being light-draft propellers with elevated cabins. The enormous traffic of the Erie and others of the long canals is as yet mostly carried in boats towed by horses and managed by companies and individual owners. Steam is, however, being introduced; the tug-boat consort and cable systems each having its advocates. Single steamers are also used to a limited extent, but are generally not considered advantageous, as the size of the hulls is restricted by the locks. The boats to and from the Erie Canal are towed on the Hudson River between New York and Albany, in fleets of 20 to 30 or upwards, by large side-wheel steamers specially adapted for the purpose.

On the lower Hudson are quite a number of propeller lines. The boats are arranged to carry freight on the lower deck, and cabins are provided above for passengers. These steamers tow barges with hulls of somewhat similar construction when greater capacity is required.

The ferry-boats on the eastern navigable rivers are a modification of the steamers. The boats are short and broad, and receive horses, vehicles, and passengers from the shore directly on the ends of the main deck, which is widened for the purpose by extending the guards. When being loaded, each boat is moored, end on, to a bridge with one end carried on a float and the other pivoted to the shore. The boats run either way, and are guided to place by pile buffers lining the slip, Passenger cabins are located at the sides on the guards, and occasionally an upper cabin is added. These steamers are made sufficiently strong and powerful to keep up communication through the ice in the hardest winters. On western rivers the ferry-boats are more like the ordinary steamers, and run only one way, as they need to head up against the current and land broadside to floats which are connected by bridges to the landings. Special ferry-boats are in use for carrying whole trains of railroad cars, and floats carrying eight to ten freight cars are towed from the termini of the lines to

freight depots at different portions of the water fronts of the cities, where the cars are often loaded and unloaded afloat.

SUBJECTS EXHIBITED.

25. *Drawing showing lines and construction of light draft stern wheel steamboat.*

This boat is of a class in very common use on the tributaries of the Mississippi. Though somewhat crude in design, it is the typical light-draft American river steamer. The drawing shows only the hull, but the arrangement of the upper works and the cabin is shown in the collection of photographs. Boats of this class carry nothing in the hold.

26. *Collection of photographs of typical stern wheel and other Mississippi river steamboats.*

27 *and* 28. *Drawings and photographs showing construction of ferry-boat and arrangement of ferry slips and bridges of the Erie Railroad Ferry at New York. Contributed by* O. CHANUTE, Chief Engineer.

The general arrangement of American steam ferries as conducted in the vicinity of New York, and on many tidal rivers in the United States and Canada, dates back to the very beginning of steam navigation, and was designed by Robert Fulton himself, in 1809, or soon after the trial trip of the "Clermont" to Albany, in 1807, had established the success of his application of the steam engine to navigation.

Almost the first use of this invention to which Fulton turned his attention, was the establishment of a steam ferry across the Hudson river, between the city of New York and the Jersey shore. He applied for a ferry lease and license in July, 1809, but a competitor having arisen in the person of Mr. John Stevens, who owned the shore line at Hoboken, and the barge ferry to that point, and who had been engaged with experiments in steam navigation since 1803, some delay resulted in settling their conflicting claims.

Leases were finally executed in March, 1811, to Fulton and his associates, under the name of the Jersey Association, for a steam ferry from the lower part of the city of New York to "Paulus Hook," on the Jersey shore (this being the local name of a projecting point of land near the southern limits of Jersey City), and to John Stevens, for a steam ferry from New York to Hoboken, near the northern limits of Jersey City.

Stevens succeeded in being the first to bring his line into operation, and in the early part of October, 1811, began running the first steam ferry-boat which plied in any part of the world.

Fulton started the first boat upon the "Paulus Hook" line in August, 1812, and the second in the following year. He obtained a ferry license across the East River, from Burling Slip, in New York, to the Fly Market, in Brooklyn, in 1813; and his general arrangement of ferry has continued in successful use ever since, with but trifling alterations.

The system was so thoroughly worked out in the beginning, that Fulton's own account of his design will stand fairly well for a description of the ferries of the present day, and the following letter, written by him to Dr. David Hosack, describing the boat, &c., which he had put into operation in 1812 upon the "Paulus Hook" line, will, doubtless, prove interesting:

Account of the Powles Hook steam ferry boat, in a letter to Dr. David Hosack, from Robert Fulton, Esq., Fellow of the American Philosophical Society, &c. (See Plate LI.)

"Sir,—At your request, I have sent you a bird's eye and side view of the Powles Hook steam ferry-boat and floating bridge, by which everything enters or is landed from her.

"My reasons for her particular form and arrangement of machinery are as follows:

"1st. She is built of two boats, each 10 feet beam, 80 feet long, and 5 feet deep in the hold; which boats are distant from each other 10 feet, confined with strong transverse beams, knees, and diagonal braces—forming a deck 30 feet wide, 80 feet long. To give her more strength, she is held together by four-inch braces, each two inches square, which pass through her one foot above the water line, and key on strong plates on the inside of each boat. Reflecting on a steam ferry-boat for Hudson's river, the waves usually running up or down, I found a great breadth of beam absolutely necessary to prevent the boat rolling in the trough of the sea. This is attained by two boats and one space, giving 30 feet beam.

"2d. By placing the propelling water-wheel between the boats, it is guarded from injury by ice or shocks on approaching the wharf or entering the docks, which operation being performed twenty-four times in twelve hours, allows no time for fending off with boathooks.

"To give despatch and convenience, it is necessary the boat should arrive at the bridge without the possibility of any injury; hence all important parts of the machinery should be carefully guarded, particularly the propelling wheels.

3d. The whole of the machinery being placed between two boats, on the beams over the open space, leaves 10 feet wide on each side, on the

PLATE I I
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FULTON'S SKETCH OF HIS FERRY SYSTEM, 1812.

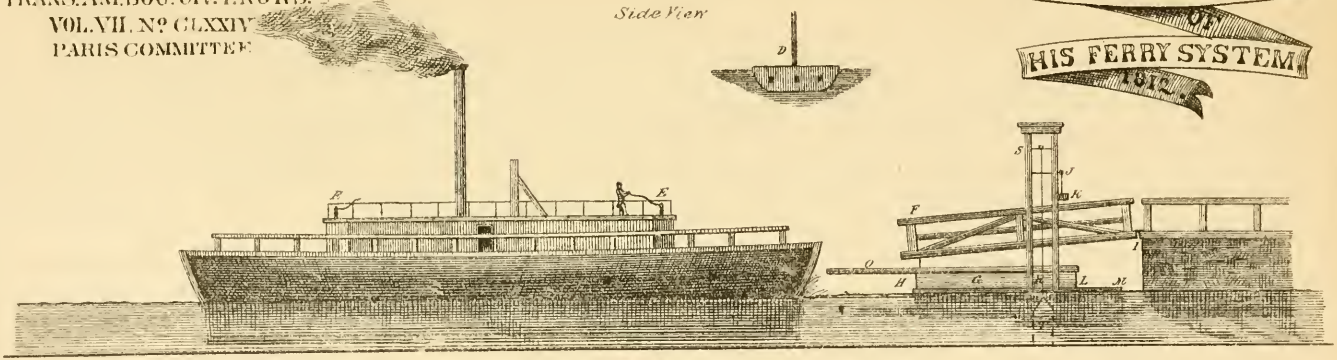

Fig. 1
Side View

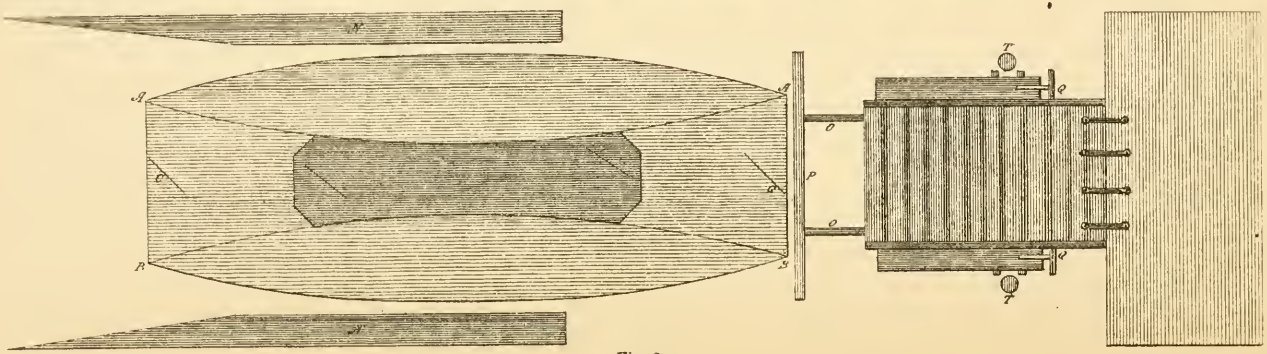

Fig. 2
Birds-eye View

decks of each boat for carriages, horses, cattle, &c. ; the other having neat benches, and covered with an awning, is for passengers. On the latter side there is a passage and stairs to a neat cabin, which is 50 feet long and 5 feet clear from the floor to the beams, and furnished with benches for passengers in rainy or bad weather. In the winter there will be a stove in this cabin, which will add much to the comfort of the passengers while navigating through the ice.

"4th. Although the two boats and space between them give 30 feet beam and proportionate stability, yet they present sharp bows to the water, and have only the resistance in water of one boat of 20 feet beam, which diminution of resistance gives speed in crossing,

"5th. The space from "stem to stern," that is, from *A A* to *B B*, of each boat. is 20 feet wide, which gives ample room at each end for carriages or persons to enter or go out of the boat.

"6th. Both ends being alike, and each having a rudder, she never puts about. At New York the horses and carriages enter at one end of the boat, the horse's head towards Jersey. On arriving they go out at the other end, without changing the line of direction ; in like manner, when coming from Jersey to New York. Thus the shortest possible and quickest movement of all that is to pass, is made to save time and secure convenience. Her rudders, which are placed as at *C C*, are equipollent—the iron shaft which serves as a rudder-post standing in the middle of each, as at *D*, by which construction. the pressure of the water being equal on each side of the centre, it can go either end foremost. With yokes and parallel bars, the movement of the rudders are carried to the helms at *E E*, the only position where the helmsman can have a full view of all around the boat, and see how to steer her into dock.

"It was at one time my intention to put a rudder on the bow of each boat, and work them by a connecting bar ; but considering that such rudders, while acting as bow, would be injured by ice or destroyed by shocks against a wharf or timbers, and knowing that the greatest current of water is exactly behind the wheel and between the two boats, I placed them as delineated, where they answer every desired purpose and are guarded from injury. In my first sketches I had made the inside line of each boat straight, that the water might have a free passage from one end to the other ; but the disadvantage of such a mode of construction would be, that the whole of the inside lines would act as leeboards, rendering it difficult to put her about or to work her up in the tide. Had this boat been moved by wind, such a form, to prevent leeway, would have been advantageous ; but moved by steam, the less water she draws, the easier she moves over it in every direction the better, her bottoms are, therefore, made rounding, with very little dead rise. Another material error which would have arisen from straight insides, would be that each bearing but half a boat, the two could not give more breadth of beam or so much buoyancy as one of the present boats ; and

to give the 30 feet beam it would be necessary to have a vacant space between the two insides of 20 feet, which long and hollow bearing would produce weakness. Such a boat, to carry the same weight, would draw near twice as much water as the present steamboats, and create a resistance in the water equal to the present resistance by breadth of beam.

7th. *F* represents the floating bridges, of which there is one on each side of the river.

G is a coffer, twenty-four feet long, twelve wide, and four deep, which gives a superficies of two hundred and eighty-eight feet, or nine tons weight to press it in the water one foot, or one thousand five hundred pounds to press it in the water one inch. This great resistance gives stability while carriages or heavy wagons enter the boat. The bridge is thirty feet long, twenty wide, fastened by four strong hinges to the coffer at *H*, and to the wharf at *I;* thus the bridge rests and falls with the tide, and is always exactly even with the end of the boat. When low water there is an easy descent into the boat ; at half flood, the boat, bridge and wharf are on a level ; at high water there is any easy descent from the boat to the wharf. As the weight of the bridge is on one edge of the coffer at *H*, to prevent its sinking on that side and rising on the other, a chain is fastened to the bridge, which passes over the pulley *J*, with a heavy weight *K*. Such an application on each side of the bridge pulls it up in the middle, and pushes down the coffer at *L*, added to which, a pine log, one foot square, is bolted on each side of the coffer, as at *M*, with two transverse logs dovetailed into them, of which the weight and leverage retain the coffer in a horizontal position. The next and last thing to be discovered, was how to make the boat arrive at the bridge without the aid of boat hooks, or any pushing or pulling or loss of time or shock, the latter being the most material to guard against ; for this purpose the dock which receives her is one hundred and eighty feet long, seventy wide ; the bridge is fastened to the middle of the bulkhead. The boat being only thirty feet wide, and the dock seventy, leaves twenty feet vacant on each of her sides ; in these, twenty feet spaces, and on the water there are floating stages made of pine logs, which lie parallel to the boat for thirty feet and then run diagonally to the extreme end of the wharves, so that the boat, when coming in, hits within the seventy feet, and the stages guide her direct to the bridge. The stages are indicated *N. N.* To prevent shocks, there are two pieces of timber, each eight inches square, as at *O*, which move on rollers, and run out between the bridge and coffer ; the two are connected by a crossbar *P*, and under the bridge by another crossbar *Q*. To this latter crossbar, and on each side of the bridge, there are ropes fastened, which ropes pass under pulleys at *S*, descend and fasten to buckets at *T*, which buckets of oak, strongly hooped with iron, are fifteen inches in diameter, six feet long, and when full of water will weigh about one thousand eight hundred pounds.

When the fenders *O* are projected to the position delineated, which is

about ten feet from the bridge, the buckets are down in the water, leaving their upper rim about three inches above the surface. *W* is the weight of the buckets, which drives the fenders out of their present position. Each bucket has four holes in the bottom, of an inch diameter, by which the water enters as they descend, and which lets out the water as they rise, In case the resistance should be too great for the boat to come close to the bridge, the water running out of the buckets will diminish it and let the boat arrive at the position required. To prevent shock the whole force must be gradually diminished to annihilation ; the resistance to the boat must be little in the commencement and increase until the whole power is destroyed. Fortunately this contrivance produces the desired effect. When the buckets are in the water, they are nearly buoyant; but the moment the boat strikes the crossbar *P*, and it begins to run in, the buckets come gradually out of water, and grow heavier each inch they rise, increasing resistance until the momentum is destroyed, and the boat arrives at the bridge without shock, when the passengers, carriages and, horses immediately move out, and others enter.

In the present state of this part of the machinery, to prevent shocks, it is necessary the men should be attentive to stop the engine in time. The most perfect machinery is that which leaves as little as possible to the care of man.

I have some additions to make which will prevent the possibility of shocks, even in cases where men may mistake or be careless. In a new combination of this kind, it is not to be expected that everything should work to the best advantage in a first experiment, or that every requisite should be foreseen. The boat which I am now constructing will have some important improvements, particularly in the power of the engine, to overcome strong ebb tides, from which again other improvements will be made. as in all other new inventions. The present boat crosses the river in a calm in fourteen minutes; her average time is twenty minutes.

She has had in her at one time, eight four-wheeled carriages, twenty-nine horses, and one hundred persons, and could have taken three hundred persons more. From the success of this experiment there is the pleasing prospect that boats of this kind will facilitate the passage of many of our wide rivers and bays, and prove an important benefit to our country.

I am, sir, respectfully,

Your most obedient,

ROBERT FULTON."

The mode in which the boats cross the river causes the chief peculiarities of the system. While, upon the steam ferries in use in other countries, the boats generally land with their sides against the shore, thus compelling a half turn at least with every crossing of the water, in the Fulton, or American system, they ply like shuttles between the shores, and are loaded and unloaded from the ends, instead of from the

sides. Thus the boats cross the river without turning, and effect a material saving of time. besides adding to the convenience in loading and unloading.

Beyond a general increase in size. but few changes have been made in Fulton's original design. Single hulls were substituted for the arrangement of double boats in 1836, and have been preferred ever since. The docks or slips have been enclosed with spring piles, itstead of the floating stages, and the ingenious buffer of Fulton has been dispensed with ; india rubber springs at the hinge of the floating bridges being substituted, while the boats are slowed upon their entrance into the slips by reversing their paddle wheels.

For ease in loading and unloading, rapidity in crossing, comfort of passengers, and cheapness of charges, this system is believed to be superior to that in use in any other part of the world.

The particular ferry selected for illustration is that of the Erie Railway. This consists of two lines from the terminus at Jersey City; one to the lower portion of the City of New York, a distance of $1\frac{1}{10}$ miles, and the other to the upper portion of that city, a little over 2 miles. These are served by four ferry boats, which make 4 trips or crossings per hour upon the lower, and 2 per hour upon the upper line. Thus they maintain a speed of about 4 miles per hour, *including the time stopping and starting and that spent in their docks.* This is generally about five minutes on the lower line, and is found amply sufficient to unload and reload 400 or 500 foot passengers, and 10 to 20 carriages.

The "Susquehanna" (the boat illustrated) is a fair representative of the line. She is of 921 tons burden, with 692 nominal horse power, and is licensed to carry 600 foot passengers, and 25 two-horse wagons) or as alternative 20 coaches, or 16 double teams.

Her cabins are lighted with gas, and warmed by steam, and provide seats for 266 passengers.

The ferriage charge is 3 cents per footman upon either line, thus being at an average rate of about 2 cents per passenger per mile.

The docks or slips into which these ferry boats run. are generally about 180 feet long, and about 90 feet wide, being curved as shown on the plans, to correspond with the shape of the boat. They are lined with spring piles, driven into the mud, which yield and spring back when struck by a boat in entering or leaving. The better to enable the latter to glance off, on such occasions, their guards are shod with iron, and slushed with some cheap grease.

In some American rivers of greater rise and fall than 5 feet, this being the mean tides in the vicinity of New York, the approaches have been made upon a series of several floating bridges, hinged end to end, and supported at their junction upon pontoons, which ground successively upon submerged piers, so as to present nearly the same inclination of roadway, at the several stages of the tide.

29. *Photographs showing interior of cabin and outside view of Mississippi river steamboat "Grand Republic." Also a photograph of a St. Louis ferry-boat which is typical of the ferry-boats used on the Mississippi and its tributaries.*

The "Grand Republic" was one of the largest and finest passenger steamers on the Mississippi river. She ran between St. Louis and New Orleans, a distance of 1 200 miles. She was one of the few Mississippi river boats provided with compound engines.

The general design of the St. Louis ferry-boat is that of two hulls with a single bow; the engine is placed in the centre, the wheel working between the hulls, and the cabin is overhead. The entire main deck, except the part occupied by the machinery and boilers is left open, and forms a standing place for teams and animals which may be driven completely around the boat. The boat lands against a float moored to the shore, and teams drive on at the side.

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30. *Engine of steamer "City of New York." Also photographs of steamers "Bristol," "Sunnyside," and "Massachusetts."*

The steamers "City of New York" and "City of Boston" were built in 1860, for the passenger and freight business between the cities of New York and New London (distance 120 miles), connecting at the latter place with railroad lines for the cities of Worcester and Boston, and other points in the interior of New England; one of these steamers leaving either terminus of the route every evening except Sunday.

Their hulls were constructed in the best manner by Samuel Sneden, from specifications of Charles W. Copeland, the superintending engineer for the steamboat company. They are not only timbered and fastened in the best manner, but have in addition, very strong hog or truss frames, well secured by iron straps and bolts, also upon the frame of the hull diagonal iron strapping of flat bar iron fitted and fastened in the manner usual in the construction of seagoing steamers, the upper end of the diagonal straps being riveted to a longitudinal iron bar 6 inches wide, which is run around the entire length of the vessel, just below the deck beams, and the lower ends terminating some distance below the floor heads. These diagonal bars are rivetted at every crossing and bolted into every timber.

For the accommodation of passengers, there are 82 private state rooms and 269 berths. The cabins and state rooms are heated by steam, which is supplied by a small boiler provided for that and other purposes, when the main boilers are not under steam.

There is an ample provision of steam and hand pumps, and other fire apparatus, ready to be brought into use in case of necessity.

These steamers are 305 feet in length, 38 feet 8 inches beam, and 12 feet 4 inches hold.

Their engines are condensing engines, and have cylinders 80 inches diameter and 12 feet length of stroke, of the lever beam type, with double or balanced poppet valves, having "Stevens" cut-off motion for working steam expansively. They have also "Sickel's" patent heart-motion with counterbalance weight, to enable the engine to be worked with ease and facility by one person.

The boilers are of the return-tubular type; the fuel used is anthracite coal, and the combustion is forced when necessary, by the use of Dempfel's patent fan blowers.

The engines and boilers were constructed by the Novelty Iron Works from the specification and drawings furnished by Charles W. Copeland. Their easy and quiet operation and economy, as well as the speed of the vessels, have been all that could have been expected, and in these respects, are not excelled by any steamers of their class.

Their paddle-wheels are 38 feet 8 inches diameter, 9 feet 8 inches length of bucket, and 28 inches width of bucket. The maximum speed of engine 19½ revolutions per minute. the average being about 17.

The average consumption of coal during the first two years of their running was seventeen tons a passage, but owing to their increased weight, by additions and other causes, the average consumption is now about nineteen tons a passage.

These steamers carry full loads of passengers and usually from 250 to 300 tons of freight.

Photographs of the exterior and interior of the steamer "Massachusetts."

The steamer "Massachusetts" was launched September, 1876, and commenced running May 7th. 1877. She was built at Greenpoint, Long Island, and the launching weight, without machinery or joiner-work, was 1 000 tons. She is 3 500 tons burden, 350 feet long, 80 feet breadth, and 16 feet depth of hold.

Her frames are of white oak, locust and cedar. Floor timbers of white oak throughout, sided, 9 inches; moulded 18 inches. Spaces between frames filled in solid, up to turn of bilge. Top timbers of locust and cedar; sided 7 inches. Main keelson and sister keelsons, nine in number, of Georgia pine, 13 by 26 inches. In addition, there are two bilge keelsons of same material, 14 inches deep. These keelsons extend entire length of vessel. The engine keelsons are of white oak and Georgia pine; length 60 feet, by 5 feet 3 inches in depth; width, 3 feet. Bilge strakes are ten in number, 9 by 11 inches, of Georgia pine. Ceiling and clamps are 6 inches thick, of Georgia pine. Deck beams of white pine, 8 by 8, to 15 by 18 inches. Deck of white pine, 3½ inches.

The frames of hull are diagonally strapped with iron bars, 4 by ⅜ inches; spaced 4 feet. The planking is of white oak; the bottom 3½ inches, the sides and tops 4 inches. The strings are of Georgia pine, 6 inches thick, three strakes in depth. The masts are five in number, 67 feet high, 18 inches in diameter; connected to each other and to the hull with stays of iron 2 inches in diameter. The truss or "hog" frame, is 40 feet high above main deck, extending the entire length of vessel; the timbers composing the same of unsual strength. The iron rods and straps combining the frame with the hull, are in proportion with the timber. The guards are protected below with lattice sponsons.

There is a grand saloon or state-room hall, arranged with gallery and second tier of rooms. There are two hundred rooms, each accommodating two persons; there are a number of large rooms. There are two hundred and twenty berths for first-class passengers. There are electric bells in each room, connecting with the steward's department. The rooms are carpeted with Wilton, Axminster and velvet; furnished with black walnut bedsteads, hair mattresses, and are excellent in every appointment. The steamer is lighted throughout (including rooms) by gas, and is heated by steam. The dining room is on the main deck. It is free from all sleeping apartments and the foul air of lower cabins. About three hundred and eighty thousand feet of lumber was used in constructing the joiner work.

The machinery is an engine of the vertical beam type, with a cylinder of 90 inches diameter, and stroke of 14 feet.

The wheels are 39 feet 7 inches diameter.

The engine is fitted with the Sickel's adjustable valve gear and a tubular surface condenser, with Lighthall's patent tube heads and tube packings. The refrigerating water is circulated by means of an independent centrifugal pump, capable of moving 6 000 gallons of water per minute. The same pump is fitted with appliances by means of which the whole capacity could be used in freeing the vessel from water in case of severe leakage.

The boilers are tubular, six in number, of steel. They are circular, 12 feet 8 inches in diameter, and each has three circular furnaces 3 feet 4 inches diameter. The boilers are placed thwartship of the vessel, in the hold, with fire-room between, fore and aft. The boilers are connected to two independent steam "drums" or chimneys, each boiler having a separate shut-off valve, which admits of their use together or separately. The smoke pipes, two in number, are 8 feet in diameter, placed "fore and aft." In addition to the ordinary steam and hand pumps for extinguishing fire, steam pipes are run to all parts of the vessel, so that by the simple turn of a valve, always under the control of the engineer, a fire can be extinguished before it has fairly started. The engine is capable of making twenty-four revolutions per minute; and when making only twenty per minute she acquires a speed of 19½ miles an hour.

The steamer "Rhode Island" is similar in style and finish, and has all the improvements of the steamer "Massachusetts." She is the fastest steamer leaving New York, and can run twenty-two miles per hour.

Both of these steamers are steered by steam, having separate engines for the purpose.

The cost of these steamers "Massachusetts" and "Rhode Island" ready for service, was $500 000 each, viz. :

Hull	$120 000
Machinery and boilers	180 000
Joiner work	90 000
Furniture and equipments	110 000

They are manned by a crew of ninety men, viz. :

Deck department	26
Engineers' department	30
Stewards' "	34

The "Massachusetts" and "Rhode Island" are owned by the Providence & Stonington Steamship Company, which operates two lines between New York City and New England, which are known as the Providence Line and the Stonington Line.

The route of the Providence Line, which was first established in 1822, is from New York City to Providence, Rhode Island, by water, a distance of 184½ miles; thence by rail to Boston, Massachusetts, a distance of 42 miles.

The Stonington Line, established 1836, is between New York and the East, the boats running to Stonington, Connecticut, a distance of 120 miles.

There were carried last season upon the steamers of the Providence Line, from May 7th to October 4th over 86 000 passengers and 224 250 tons of freight. The Stonington Line steamers carried 56 270 passengers and 327 130 tons of freight.

RAILROAD ROLLING STOCK.

In no department do American railroads differ more from those of Europe than in the rolling stock which runs upon them. Originally of cheap and inferior construction, with sharp curves and irregularities of surface, these railroads demanded rolling stock of more flexible character than was needed on the more expensive roads of Europe.

In the construction of cars, this object was accomplished by the use of the independent truck; which enabled long cars to pass without difficulty around very sharp curves, and accommodated itself to the irregularities of the track, transmitting to the body of the car simply the resultant of the movements as felt at the centre, where the connection is made with the pin. This truck system is in universal use; the details of the different trucks differ materially, some being largely of wood, and others almost entirely of iron; but the one principle which is everywhere followed is to hang the long body of the car on two independent trucks, which are free to rotate on pins, and which follow the curve of the track, while the body of the car takes the position of a chord. The only exceptions are in short cars used for coal, and other heavy freights, which have but four wheels, and a few larger coal cars of peculiar design in which the axles are kept parallel, but free to move transversely for a moderate distance.

American railroad cars may be grouped under the two general classes of passenger train equipment and freight train equipment.

The passenger train equipment includes besides the coaches in which passengers ride, the baggage, mail and express cars, which are carried on the same train. An express train on a long line is usually made up in the following manner: a mail car, placed next to the engine, and provided with all arrangements for distributing mails, and for receiving and delivering mail bags at stations where the trains do not stop; an express car used exclusively for express freight; a baggage car for the baggage of passengers on the train; two or more day passenger coaches, each seating about 54 people; one or more sleeping cars. On some of the less important lines, a single car, divided into compartments, is made to answer for mail, baggage, and express, while on the other hand, on many railroads much longer trains are required. A fully equipped first-class passenger train is illustrated by the photographs of a train on the Pennsylvania Railroad, with a description of each class of cars.

The principal varieties of freight cars in use are: the flat car, a single uncovered platform; the box car, a house car with doors on the sides; the stock car, with tight roof, but sides made with open slats, for carrying cattle; the oil car, which consists of a platform carrying an air tight boiler shaped tank of iron; and the coal car, of which there is a great variety of patterns. All of these cars, except the coal cars, are built with two trucks and eight-wheels of chilled cast iron, and measure about 30 feet in length as they stand in a train. For grain and general merchandise the eight wheel box car is universally used; these cars weigh from 17 000 to 20 000 pounds, and carry from 22 000 to 28 000 pounds. A freight train is made up of freight cars of different varieties, to which is always added at the rear a "caboose," which is a small car of plain construction, in which the tools, lamps and outfit of the crew are carried, and which is the headquarters of the conductor of the train.

The standard American locomotive for both passenger and freight traffic is the eight-wheel engine. The first engine of this class is said to have been designed by Mr. Henry R. Campbell, of Philadelphia, in 1836, though the "equalizing beams" by which the weight is distributed on the driving wheels were introduced somewhat later by Mr. Joseph Harrison, Jr. The forward end of the engine rests on a four-wheel truck which carries about one-third of the whole weight, the other two-thirds being equalized on two pairs of driving wheels. In 1851 this class of locomotives had substantially its present appearance, but was different in many details. It was then usual to make the locomotives with cranks

and inside cylinders, and the reversing of the valve was accomplished with the so-called hook motion. About the year 1855, outside cylinders and the shifting link valve motion came into use.

The earlier locomotives with outside cylinders had a rectangular smoke box and the cylinders were bolted to it; this arrangement answered very well so long as the locomotives were small, but as their size increased it became customary to make the smoke box round and to fasten the cylinders to a large casting called the saddle, upon which it rested; this was a decided improvement, but not so good as the present practice of casting one-half of the saddle with each cylinder, the two cylinders being of the same shape and interchangeable.

For switching cars in yards small locomotives, the whole weight of which is carried on two or sometimes three pairs of driving wheels, are commonly used; they are often built with tanks over the boiler, so as to dispense with tenders, but this practice is by no means universal.

Upon railroads where locomotives of greater power than the standard eight-wheel engine are required, the practice was formerly to use a "ten-wheeler," the peculiarity of which was that it had three pairs of driving wheels instead of two, the other features of the eight-wheel engine being retained. On the Baltimore & Ohio Railroad, a locomotive of peculiar construction, known as a "camel" has long been in use; the entire weight is carried on four pairs of driving wheels; the cylinders are outside connecting with the third pair of wheels and the cab is placed on top of the boiler, directly behind the smoke stack, giving the engine a singularly ungainly look. But the two classes of locomotives which are now generally preferred for heavy freight traffic, especially on heavy gradients, are the "Mogul" and the "Consolidation" engines, both of which are fully illustrated in the Society's exhibit.

The "Mogul" has three pairs of driving wheels connected and a two-wheel swing truck in front, equalized with the front driving wheels. It has rapidly grown in favor for freight service on heavy grades or where maximum loads are to be moved, and has been adopted by several leading lines. Utilizing, as it does, nearly the entire weight of the engine for adhesion, the main and back pairs of driving wheels being equalized together, as also the front driving wheels and the pony wheels, and the construction of the engine, with swing truck and one pair of driving wheels without flanges, allowing it to pass short curves without difficulty, the "Mogul" is generally accepted as a type of engine especially adapted to the economical working of heavy freight traffic.

The original engine named the "Consolidation" was built in 1866 to operate a grade of one in forty on the Lehigh Valley Railroad; it had cylinders twenty by twenty-four inches, four pairs of driving wheels, connected, forty-eight inches in diameter, and a two-wheel swing truck in front, equalized with the front driving wheels. The weight of the engine, in working order, was ninety thousand pounds, of which all but about ten thousand pounds was on the driving wheels. This engine was the first of a class to which it has given its name, and which are now recognized as the most powerful freight engines in use.

SUBJECTS EXHIBITED.

31. *Photograph of locomotive and of coal chute bridge in use on Philadelphia, Wilmington & Baltimore Railroad. Designed by* S. T. Fuller, C. E.

This bridge, which is of iron, placed over the four tracks, has a clear height above same of 18 feet and a clear width of 16 feet, on which is laid a track of 3 feet gauge for the dump cars. On the side of the railroad, at end of and grade of "coaling bridge," is a storehouse, capable of holding 800 tons of coal. This storehouse is reached by a track about 1 000 feet long, extending from grade of railroad along the top of slope, over which the coal is taken in ordinary cars, the grade of track in storehouse allowing the coal to be dumped through the bottom of the cars. Tracks and turn-tables are provided to allow the coal to be loaded into cars holding one ton, and in any part of the storehouse, and moved by hand, passing over a scale to the chutes on coaling bridge. These chutes are of wrought iron, 18″ x 24″, 9 feet long, and are hung to a shaft on under side of bridge, the shaft passing through the upper side of the chute, so that their lower ends, when in position, will be in centre of track. They are balanced by a movable weight on the end of an attached lever, so that they will, when not in use, hang up under the bridge. An engine is coaled in from one-half minute to a minute and a half, without dust.

The second photograph shows the same general arrangement, except that the coal is raised vertically by steam power after being loaded in small cars, the storehouse being at grade of railroad; and there are two chutes on each shaft, which allows two cars to be dumped at once, and at different places in the tender.

32. *Detail Drawing of Sleeping Car. Built by* Messrs. Gilbert, Bush & Co.

33 and 34. *Photograph and Detail Drawing of Consolidation Locomotive. Built for Erie Railway by* BROOKS LOCOMOTIVE WORKS, *according to following Specification.*

Dimensions.—Cylinders, 20″ dia. and 24″ stroke. Drivers, 50″ dia. outside of tires. Gauge, 4 ft. 8½ inches. Fuel, anthracite coal. Total wheel base of engine, 22′ 10″. Driving wheel base, 14′ 9″. Weight in working order—total—about 100,000 lbs. Weight on drivers, about 88,000 lbs.

Boiler—Made throughout of best quality of Otis steel $\frac{7}{16}$″ thick, Riveted with $\frac{13}{16}$″ rivets placed not over 2¼″ apart from centre to centre. All horizontal seams to be double riveted; all parts well and thoroughly stayed, and extra welt pieces riveted to inside of side sheets. providing double thickness of metal for studs of expansion braces. All seams to be properly caulked. Boiler tested to 180 lbs. pressure per square inch.

Waist.—54″ dia. at smoke box ends; made telescopic and with one dome placed over fire box—double flanged—smoke box of ½″ iron.

Tubes—Of iron, No. 13 W. G., 200 in number, 2″ outside diameter, and 135½ inches in length between tube plates, 2⅝ inch centres of tubes.

Furnace—Of best quality Otis steel, 123 inches long and 33⅝ inches wide inside of mud ring, and 44 to 56¾ inches deep from bottom of mud ring to under side of crown sheet (front and back ends), all plates to be thoroughly annealed after flanging; side and back sheets $\frac{5}{16}$ inches thick, crown sheet ⅜ inch thick, flue sheets ½ inch thick, water space 3 inches at sides and back, increasing in width at top, water space in front 4 inches; stay bolts, made of best Ulster iron, ⅞ inch dia., screwed and riveted to sheets, and not over 4½ inches apart from centre to centre.

Crown Bars—Crown sheet supported by crown bars, made of two pieces of wrought iron, each 4½″x⅝″ section, set ⅞ inch above crown, placed $5\frac{1}{16}$ inches centres, and bearing on side sheets, crown stayed by braces to dome and outside shell of boiler.

Cleaning Holes.—Cleaning plugs in corners of firebox, and blow off cock in front.

Throttle Valve—Balance throttle valve of cast iron placed in dome.

Grates—Of iron tubes 2″ outside dia. No. 4 W. G.

Ash Pans—With cast iron frames and slides.

Smoke Stack—Erie Railway standard.

Main Frame——Of best hammered iron made in three sections—main frames forged solid.

Front Rails.—Front rails bolted and keyed to main frames, and with front and back lugs forged on for cylinder connections.

Pedestals—Pedestals protected from wear of boxes by cast iron flanged wedges. Pedestal caps lugged and bolted to bottom rails of frame.

Truck.—Swinging, centre bearing, two wheeled truck, two double plate chilled wheels of approved make 30″ diameter.

Axles—Of best hammered iron, with inside journals, 5″ diameter and 10 inches long.

Springs—Of best cast steel, tempered in oil.

Cylinders—Of best close grained iron as hard as can be worked—each cylinder cast in one piece, with half saddle, placed horizontally: right and left hand cylinders reversible and interchangeable, accurately planed, fitted and bolted together. Oil valves placed in cab and connected to steam chests by pipes running under jackets. Pipes proved to 200 lbs. pressure.

Pistons—Heads and followers of cast iron, fitted with Dunbar packing. Piston rods of best hammered iron, ground and keyed to cross heads, and secured to piston head with brass nut.

Guide—Of wrought iron, case hardened, fitted to wrought iron guide yoke.

Crossheads—Of wrought iron, with wrist pin of wrought iron, case hardened.

Valve Motion.—Most approved shifting link motion, graduated to cut off equally at all points of stroke. Links, blocks, pins, lifting links and eccentric rod jaws made of the best hammered iron, well case hardened. Rocker shaft and reverse shaft of wrought iron, with arms forged on, except vertical arm of reverse shaft, which is to be keyed on.

Driving Wheels.—Eight in number, 50 inches in diameter, centres of cast iron, with hollow spokes and rim, and turned to 44 inches diameter to receive tires.

Tires—Of steel, 3 inches thick when finished, 3 pair flanged 5¾ inches wide, 1 pair plain 6″ wide—the plain tire to be placed on the main wheels.

Axles—Of hammered iron, excepting main axle, which is to be of steel—journal 7″ dia. and 8 inches long. Driving boxes of cast iron, with brass bearings.

Springs—Of best cast steel, tempered in oil.

Rods—Connecting and parallel rods of best hammered iron, forged solid, furnished with necessary straps, keys and brasses. Parallel rod brasses to be babbitted, the grooves for babbitt to run full length of bearings.

Crank Pins—Of hammered iron, except main pins which are to be of steel.

Feed—To be supplied by one injector and one pump, or two injectors, as directed.

Water—Guide yoke made with lugs for 2 pumps, in case they are required.

Cab—Substantially built of hard wood, well seasoned and finished, and fitted together with joint bolts and corner plates.

Pilot—Oak frame and ash slats.

Finish—Cylinders lagged with wood, and neatly cased with Russia

iron. Heads of cast iron, painted. Steam chests with cast iron tops, bodies cased with sheet iron. Dome lagged with wood, with sheet iron casing on body, and cast iron top and bottom rings. Boiler lagged with wood, neatly jacketed and secured by iron bands.

Furniture—Engine to be furnished with sand box, brackets and shelf to receive head lamp, bell, whistle, heater, blower and safety valve, steam gauge, cab lamp, gauge cocks, oil cans and tallow pot. Also a complete set of tools, consisting of two jack screws, one pinch bar, a complete set of wrenches to fit all bolts and nuts on engine, one monkey wrench, hammer, chisels, cab seat cushions, poker, scraper and slice bar.

Painting.—Engine and tender to be painted and varnished.

Gauges—General features of construction—all principal parts of engines accurately fitted to gauges and templates and thoroughly interchangeable.

Case Hardening—All finished movable nuts, and all wearing surfaces of machinery, to be of steel or wrought iron, case hardened.

Threads—To be United States standard, as designed by Wm. Sellers for Franklin Institute, of Philadelphia. Absolute accuracy in this insisted upon.

Tank—Tank strongly put together with angle iron corners, and well braced. To be made of $\frac{3}{16}$ iron, riveted with $\frac{3}{8}$ rivets. $1\frac{1}{4}$ inches pitch. Capacity 2,500 gallons.

Frame—Of wrought iron, as per tracing.

Truck—Of wrought iron frames, with wooden battens; chilled wheels, of approved make, 30 inches dia.; brakes on rear tender truck.

Axles—Of best hammered iron; outside journals $3\frac{1}{4}$ inches dia. and 7 inches long; oil tight boxes, with brass bearings.

Tool Boxes—Of hard wood, bound with iron—one box at back end of tender frame, and two boxes on top of tank.

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35. *Photograph and Detail Drawing of First-class Passenger Coach. Built by the* Wabash Railway Company.

Wabash Railway, Coach No. 6. Extreme length of car, including platform, 60 feet 5 inches. Width over all, 10 feet 4 inches. Outside height, 10 feet 4 inches. Car is furnished with Miller platform and wrought-iron drawbar. Has two six-wheel trucks. Extreme length of truck, 13 feet. Width, 6 feet $7\frac{1}{4}$ inches, with wheel centres 4 feet 8 inches apart.

Interior of car. Extreme inside length, 53 feet 3 inches. Inside width, 9 feet. Inside height, 9 feet 4 inches. Inside width of upper deck (monitor top), 4 feet 8 inches. Finished with white ash with black walnut trimming. Number of windows, 40, 18 on each side of car and

2 at each end. Door at each end of car. Car contains 15 double seats on a side, seating 60 people. Cushions upholstered with red plush, with green plush backs. Saloon at each end of car. Car is heated by two hot-air stoves.

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36. *Detail Drawing of Freight Locomotive. Mogul pattern, in use on Louisville & Nashville Railroad. Designed by* FRED. DE FUNIAK, C. E. and M. E.

The engine is outside connected and supported on eight wheels, three pairs of which are coupled driving wheels, one pair of them behind, and two pairs in front of the furnace. The front end of engine is supported by a single pair of truck wheels. Rigid wheel-base 15 feet. Total wheel base of engine 22 feet 4 inches.

Cylinders.

Are horizontal, 18 inches diameter, with 24 inches stroke of piston, and 84 inches apart from centre to centre; half the "saddle" or bed plate is cast on each cylinder.

Driving Wheels.

Of cast iron, with steel tires shrunk on. Rear and front pair with flanged tires 5½ inches wide. Middle pair with flat tires 6 inches wide. Diameter of drivers 54 inches.

Engine Frame.

Solid bar iron 3 × 4 inches with the pedestal jaws forged on. Front end of frame securely bolted to the cylinder bed or saddle.

Engine Truck.

Single pair of truck wheels 30 inches diameter in radiating frame, and connected by equalizing levers with the front drivers.

Boiler.

Straight on top, with one steam dome, Shell of boiler ⅜ iron. Smallest ring of waist 50 inches diameter. Furnace outside 5 feet 8 inches, by 5 feet 7½ inches. Fire box of steel 61½ inches by 36¾ inches inside; tube sheet ⅜ inches, sides and crown-sheet $\frac{5}{16}$ inches. Tubes 170 of lap-welded C. C. iron 2 inches outside diameter by 11 feet 4 inches long with ⅝ inch water space between them.

Heating Surface.

In fire box	102	square feet.
" tubes	1020	" "
Total heating surface	1122	" "

Grate Bars.

Of cast iron, in pairs, have journals on ends and arranged for rocking motion. Amount of grate surface 15½ square feet.

Smoke Stack.

Of cast iron $\frac{5}{16}$ inch thick with a deflecting cone casting in top and spark arrester of No. 10 steel wire four meshes to inch across the top.

Valve Motion.

Slide valves of the "*D*" pattern, with $5\frac{1}{4}$ inch travel. Outside lap $\frac{1}{8}$ inch. Valves are connected to upper arms of rockers by valve stems, the lower arms of rockers are attached to the usual "shifting" links connected by eccentric rods to eccentrics on the main driving axle.

Tender.

On eight wheels 30 inches diameter. Capacity of tank 2 800 gallons; with space for 200 bushels of coal. Weight of tender empty 18 500 pounds.

Weight of Engine.

On driving wheels	66 000	pounds.
On truck wheels	14 000	"
Total weight in running order	80 000	"

NOTE.—There is no pump on engine, the feed water being supplied to boiler by two No. 7 improved injectors.

38. *Photographs of Locomotives, built by* DANFORTH LOCOMOTIVE & MACHINE COMPANY.

39. *Photograph of Snow Plow on Kansas Pacific Railway,*

40. *Detail Drawings of Freight Cars with iron trucks in use on the Chicago, Burlington & Quincy Railroad.*

Three patterns, viz., box cars for grain; combination cars for cattle or goods and flat cars.

41. *Drawing of Iron Coal Car.*

The peculiarity of this car is the attachment of the axles to the body of the car; the attachment being made by side levers which are pivoted at the centre, thus allowing the axles to move transversely, but keeping them always parallel.

42. *Photographs and Drawings of Passenger and other Locomotives. Fireless locomotives in use in New Orleans.*

These fireless locomotives are used on street railways ; they are charged with steam to a pressure of 120 pounds, and run two and a half miles and back, the steam pressure being reduced to 60 pounds at the end of the five mile trip.

Photographs of Locomotive and Passenger Train on the Pennsylvania Railroad. (See Plate LII.)

The train is composed of a Passenger Locomotive and nine cars. Westinghouse automatic air brake of the latest arrangements ; there are also hand brakes acting independently of the air brakes. Janney Coupler, side buffers and platform recently adopted by the Pennsylvania Railroad.

Locomotive 64 is a Pennsylvania Railroad standard class "*C*," Locomotive for burning bituminous coal. The cylinders are 17 inches by 24 inches. The driving wheels are 62 inches in diameter. The boiler is of steel, and contains 155 iron tubes, 2 inches inside diameter, $128\frac{1}{16}$ inches long. The fire grate area is 17.6 square feet, and total heating surface of tubes and fire-box 1056.98 square feet. The weight of the locomotive ready for the road is 75 500 pounds. The tender has a capacity of 2 400 gallons of water and 8 000 pounds of coal, and is fitted with water scoop for taking up water while running, for which purpose water troughs are located between the rails at certain points.

United States Postal Cars 24 and 25 (both alike), length 60 feet. width 8 feet 7 inches, height 9 feet 4 inches. The cars have doors at both ends and two double doors on each side ; there are 11 windows on sides and 36 in upper deck. Each car contains the following furniture : Bin 22 feet 5 inches long, divided by upright posts into 5 compartments for storing pouches. Bin 16 feet 3 inches long divided by upright posts into 3 compartments for storing pouches. Two racks 16 feet long, 2 feet wide with hooks for hanging mail bags. One rack 5 feet 6 inches long, 3 feet wide with hooks for hanging mail bags. One table 2 feet 5 inches high, 26 inches wide, 17 feet 2 inches long, with mail boxes, drawers and closets underneath. One table 16 feet long, 2 feet 2 inches wide ; one letter case on end table, containing 600 pigeon holes 4 inches by $4\frac{1}{4}$ inches. Two paper cases containing 16 pigeon holes each, eight being 10 inches wide and 21 inches deep ; seven 12 inches wide and 21 inches deep, and one $12\frac{7}{8}$ inches by 21 inches deep. Besides the above mentioned furniture each car contains a water closet, Baker heater, wash stand, closet for clothes, water reservoir and the necessary lamps. The weight of these cars when empty is about 51 000 pounds each. The average weight of mail matter carried per records, is as follows :

General daily average for 70 days	9 862 pounds.
Daily average for highest 7 days	15 745 "
Maximum one day	18 537 "

The cars are carried on six wheeled trucks.

Express Car 46 is of the ordinary style used by the Pennsylvania Railroad. Length of body 40 feet 1½ inches; outside width 9 feet 4¼ inches; outside height, 8 feet 1 inch. Sliding doors on sides, 5 feet 6 inches wide, end platforms but no end doors, thus cutting off communication with the train in order to ensure safety of express matter; ventilators on sides but no windows. Hand brake can be applied as well from inside of car as from the end platforms. The weight of this car is about 30 000 pounds. The car is carried on four wheeled passenger car trucks, Pennsylvania Railroad standard.

Baggage car No. 70 is 40 feet 1½ inches long outside, 9 feet 4¼ inches wide outside, 8 feet 1 inch high outside; has side doors 5 feet 6 inches wide, end doors 2 feet 1 inch wide, and 2 windows on each side, also end platforms. Hand brake can be applied from inside of car. The weight of this car is about 30 400 pounds. The car is carried on four wheeled passenger car trucks, Pennsylvania Railroad Standard.

Passenger Cars 574 and 578 (both alike). The length of body is 46 feet 7 inches, outside; the width, at cornice, 9 feet 8 inches; 10 feet 8⅝ inches high. These cars will seat 54 passengers each. At one end of the car is a cabinet containing urinal and water-closet, also the water tank for ice water; on the outside of the cabinet is the water spigot and splash basin. There are fifteen windows on each side, two at each end, besides a glass panel in the doors; the upper deck has thirteen lights on each side; these latter are movable, so as to act as exhausting ventilators. The finish of the car is in maple, cherry and ash. The cars are carried on four-wheeled passenger car trucks. The weight of each car is about 39,000 pounds without passengers.

Pullman Palace Parlor Car, No, 209. The length of car is 58 feet 1 inch; width, at eaves, 9 feet 11 inches. It contains, in addition to the main compartment, two drawing-rooms, 6 feet 6 inches by 7 feet (seating five persons each). Total seating capacity, forty-four persons. The car is lighted by thirty-four windows on the sides, and twenty-four ventilators or deck sash openings. The trucks are of the six-wheeled patern used on Pennsylvania Railroad. The total weight of car, without passengers, is 54,000 pounds.

Pullman Palace Sleeping Car, No. 272. The length of car is 52 feet 2 inches; width, at eaves, 10 feet 0½ inches. The car contains, in addition to the main compartments, a state room 6 feet by 32 inches, seating four persons. Total seating capacity, fifty-four persons. The trucks are of the six-wheeled Pennsylvania Railroad pattern. The total weight of car, without passengers, is 54,000 pounds.

Pullman Palace Sleeping Car, No. 291. The car has a length of 56 feet; a width, at eaves, of 10 feet 1 inch. The main compartment seats forty-six persons, and the smoking room, 6 feet by 6 feet, four persons. The car is lighted by eight single and thirty double windows, and has thirty-four ventilators in deck, and end ventilation. The trucks are of the six-wheeled pattern. The total weight of the car, without passengers, is 55,000 pounds.

RIVERS AND HARBORS.

The river and harbor improvements in the United States have been, with very few exceptions, executed by the General Government. Previous to the late civil war quite a number of small works were undertaken, and also some of considerable importance. Among the more extensive earlier works was the Delaware Breakwater, a structure of considerable size and importance, as forming a harbor of refuge immediately north of Cape Henlopen, at the entrance to Delaware Bay. Another important improvement early discussed was the removal of the rocks at Hell Gate, in the easterly entrance to the New York harbor, which has been so successfully carried out within the past few years. Since the civil war the field of government improvements has been greatly enlarged, and there is scarcely a navigable stream in the country upon which some work has not been done in improving the channel. Almost every harbor on the coast has also been the subject of small annual appropriations to improve its entrance.

A very complete description of the Government works will be found in the Annual Reports of the Chief of Engineers United States Army, for the years from 1866 to 1876, inclusive. A general report of the works in progres up to that time was made in 1866, since which time the annual reports describe what has been done during each year. There are also many valuable reports relating to rivers and harbors among the professional papers of the Corps of Engineers. Among them is the Report upon the Physics and Hydraulics of the Mississippi River, by Generals Humphreys and Abbot.

Among the more important works now in progress are the New York Harbor Improvements, which embrace the removal of the remaining obstructions at Hell Gate, in the East river, by the United States; the construction of a permanent masonry wall, with projecting piers, around the city, the improvement of the channel of the Hudson river and connecting the Hudson and the lower Harlem river by a ship canal across Manhattan Island, thus opening navigation between the Hudson and the East river or entrance to Long Island Sound.

The most noted work now going on is, perhaps, the construction of the jetties at the mouth of the South Pass of the Mississippi river. This work has been vigorously pushed by its originator. The jetties have been constructed of mattresses of fascines loaded with stone, and extended to the length originally proposed. By the aid of dredging between the jetties in places, in connection with the scouring effect secured by the jetties, a channel has been obtained more than 22 feet in depth.

The very important question of embanking the Mississippi to protect and reclaim the great alluvial tracts upon each side, as a Government measure, is now being agitated. Thus far the the levee system has been carried on by State Governments and private enterprise, and has been but imperfectly done.

Another great scheme of improvement along the Atlantic seaboard, which was proposed some forty years ago, is now likely to be carried out. This is an internal water communication from New York to Florida. There is a chain of salt water sounds just back of the outer coast, extending through North and South Carolina and Georgia, that can be made available for a continuous water communication, and there is already a communication for small craft from New York to Newbern, North Carolina. A canal is now projected between the Neuse and Cape Fear rivers in North Carolina, as part of the general scheme.

The National Government is at present conducting two important surveys relating to navigation. One, the coast survey embracing the entire seaboard, and the other the survey of the Great Lakes : both of which are being executed with great accuracy. The coast survey is under the immediate control of the Treasury Department, and is chiefly conducted by civilians, while the Lake survey is under the immediate control of the War Department, and is conducted by the United States Engineer Corps.

SUBJECTS EXHIBITED.

43 *and* 44. *Photographs of detail drawings of Iron Snag Boat "McComb," built for use on the Missouri river. Designed by* Major CHARLES R. SUTER, Corps of Engineers, U. S. A.

The Missouri river is a stream of very changeable regimen ; it is constantly washing its banks and changing the course of its channel ; large

quantities of drift wood are brought down by every flood, among them logs and entire trees which caught in the bottom of the river often remain anchored there, the upper end being a little above or below the surface of the water; these are the well known snags so dangerous to navigation. The "McComb" was built to remove them, and is provided with a variety of machinery for pulling them up and cutting them in pieces.

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45. *Photograph of Mouth of Hell Gate Mine, New York Harbor.*

46. *Photographs of Dredge Boats, one pattern furnished by Vulcan Iron Works, Chicago; one by* W. H. Newton, C. E., of Chicago; *one by* R. G. Packard, C. E., of Brooklyn.

Description of the Atlantic Dredging Company's Dredge Boat No. 6. Built by R. G. Packard, C. E. See Plate LIII.

This dredge, which is equipped with a grapple, opening 15 feet for stone, and a pair of clam-shell buckets containing 10 cubic yards for mud, is capable of dredging in 150 feet of water. The hull is 115 feet long, 37 feet wide, and 12 feet depth of sides.

The cylinders (2) are 26″ diameter and 24″ stroke, horizontal and reversible, working together upon one shaft, driving two drums 3′ in diameter, which drums have friction clutches 12′ in diameter. The pinions and gears of these main drums are 3′ and 12″ in diameter, 4″ pitch and 12″ face. The two main chains are short linked, made of Burden's *best* wrought iron, 1½″ in diameter. In lifting heavy weights, which are sometimes from 50 to 60 tons, both chains are used.

The dredge is moved by six horizontal winch heads, actuated by independent engines, which will pull it, with loaded scow, against a 7 or 8 mile current; each winch head has its own friction clutch and band, so that either or any can be driven while the others hold.

Besides the ordinary anchors, the forward end of the dredge is held by an oak spud, 2′ x 2′, 50′ long, worked by a friction drum driven by the auxiliary engines.

The boiler is 18′ 4″ long, 7′ diameter, and has 2 furnaces 9′ long; 10 flues 7′ long, and 65 four-inch return flues each 16′ long; it will carry 85 lbs. of steam.

When dredging in mud two buckets full per minute are deposited in scow alongside, when the depth is not over 20 feet.

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47. *Photograph of hull of United States Dredge Boat "McAlister." Designed by* Edward Marsland, C. E.

The propeller screw of this boat is used to loosen the material, which is then removed by a current of water produced by a pump.

PLATE LIII.
TRANS. AM. SOC. CIV. ENG'RS
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48. *Detail Drawings showing system of Levee Construction in Louisiana. Contributed by* LOUISIANA BOARD OF STATE ENGINEERS.

These comprise four maps, viz. :

A map of a "cut-off," which is the most active agent in causing the caving of banks, the destruction of levees and the opening of crevasses.

Two maps of a crevasse, one of the immediate scene and the other of the country devastated. Crevasses chiefly occur on the concave sides of bends from the caving of banks and of the levees located thereon. Accretions form on the opposite point.

A map with sections and profile of a levee built to close a crevasse.

The "cut-off" selected as a type is at Davis Bend, about four hundred and sixty miles above the head of the passes of the river and three hundred and fifty-four miles above the City of New Orleans. Here the concave bends above and below the point caved in, until, in 1867, the neck or isthmus was broken through, and twenty miles eliminated from the length of the river. The fall of these twenty miles was three-tenths of a foot per mile, or five feet for the entire distance, which was concentrated into one-half mile by the "cut-off." The river immediately began to restore its length and regimen by cutting into the concave banks of all bends above and below. This result was distributed with an energy diminishing, but still sufficient to necessitate the construction of new levees, at each bend for seventy-five miles above and one hundred and twenty-five miles below the "cut-off."

The type of crevasses selected is at Bonnet Carré, one hundred and forty miles above the head of the passes and thirty-four miles above the City of New Orleans. In this bend five crevasses have occurred in the last twenty-five years. The present break has been running since 1874. It overflows upwards of one hundred square miles of land, capable of producing a crop of 2 000 pounds of sugar per acre, and a large swamp tract. Lake Pontchartrain, in the rear of the crevasse, valuable for navigation, sanitary and drainage purposes, is much impaired by deposit brought in the water from the crevasses.

The closing of crevasses is exemplified by a map of the "Bass Levee," built in 1877, about five hundred and fifty miles above the head of the passes. The crevasse closed thereby had been running since 1873, with results more disastrous than those at Bonnet Carré. The new levee is five and a half miles long, height varying from 6.5 to 21.3; average 10.8 feet. Slopes 3 to 1. Contents 487 991 cubic yards. Cost $120,373.$\frac{67}{100}$, at 24 cents per cubic yard.

Two Models of the South Pass of the Mississippi River, showing Jetties constructed by JAMES B. EADS, C. E.

The first model represents the mouth of the South Pass as it was in May, 1875. It shows the eastern and western land ends, and the gradual rise of the bottom towards the crest of the bar. The upheavals

of the Gulf bottom beyond the bar-crests are the mud lumps, characteristic in the formation of the delta of the Mississippi River. The soundings which have been used in the preparation of this model were made by the officers of the United States Coast Survey, as shown by their chart, in May, 1875. The depth which then could be carried over the bar into the Gulf of Mexico was nine feet at average flood tide.

The second model represents the mouth of the South Pass as it was in April, 1878, after being improved for navigation by the application of jetties. The location of the jetties is indicated by light colored walls, and the height given to them corresponds with the elevation the stone-covering will have after the jetties are finished.

The jetties are constructed of willow mattresses, which are sunk by stone. The small dams projecting into the channel are wing dams of temporary character and importance; they are designed to hasten the scour in the centre. The soundings which have been used in the preparation of this model were made in April, 1878.

By comparing the two models with each other, the following facts will appear:

1. A channel has been excavated throughout the entire length of the old bar large enough to permit the passage of ocean vessels of 23½ feet draft from New Orleans to the Gulf.

2. No new formation of the bar beyond the sea ends of the jetties has taken place. The models show the summits of the old lumps to have been worn away by the power of the deep fresh water current which emerges from the mouth of the jetties.

3. The bottom at the sea sides of the jetty walls has filled up nearly to the height of the jetties, thus giving a complete protection to the jetties from storms and waves.

4. Considerable changes in the outlines of the shore line have taken place, due to the confinement of the water in one narrow channel.

Drawings of Inclined Plane and Caisson connecting the Chesapeake and Ohio Canal with the Potomac River at Georgetown, D. C. William R. Hutton, Engineer. (See Plate LIV.)

The work consists of a caisson, in which the barge floats, traveling upon the rails of an inclined plane from the head bay at the Canal, to descend into the water of the river. It is balanced by two counterweights, and the motive power is supplied by a turbine wheel, worked by water from the canal, which turns the grooved pulleys around which the cables pass which connect the caisson with the counterweights. The caisson is of plate iron and rolled beams, the counterweights are timber frames filled with masonry.

Each cable is attached to the head wall, passes through a sheave on the counterweight, makes two and a half turns around the pair of grooved

CANAL CHESAPEAKE - OHIO

ÉCLUSE A PLAN INCLINE
PRÈS WASINGTON — ÉTATS UNIS

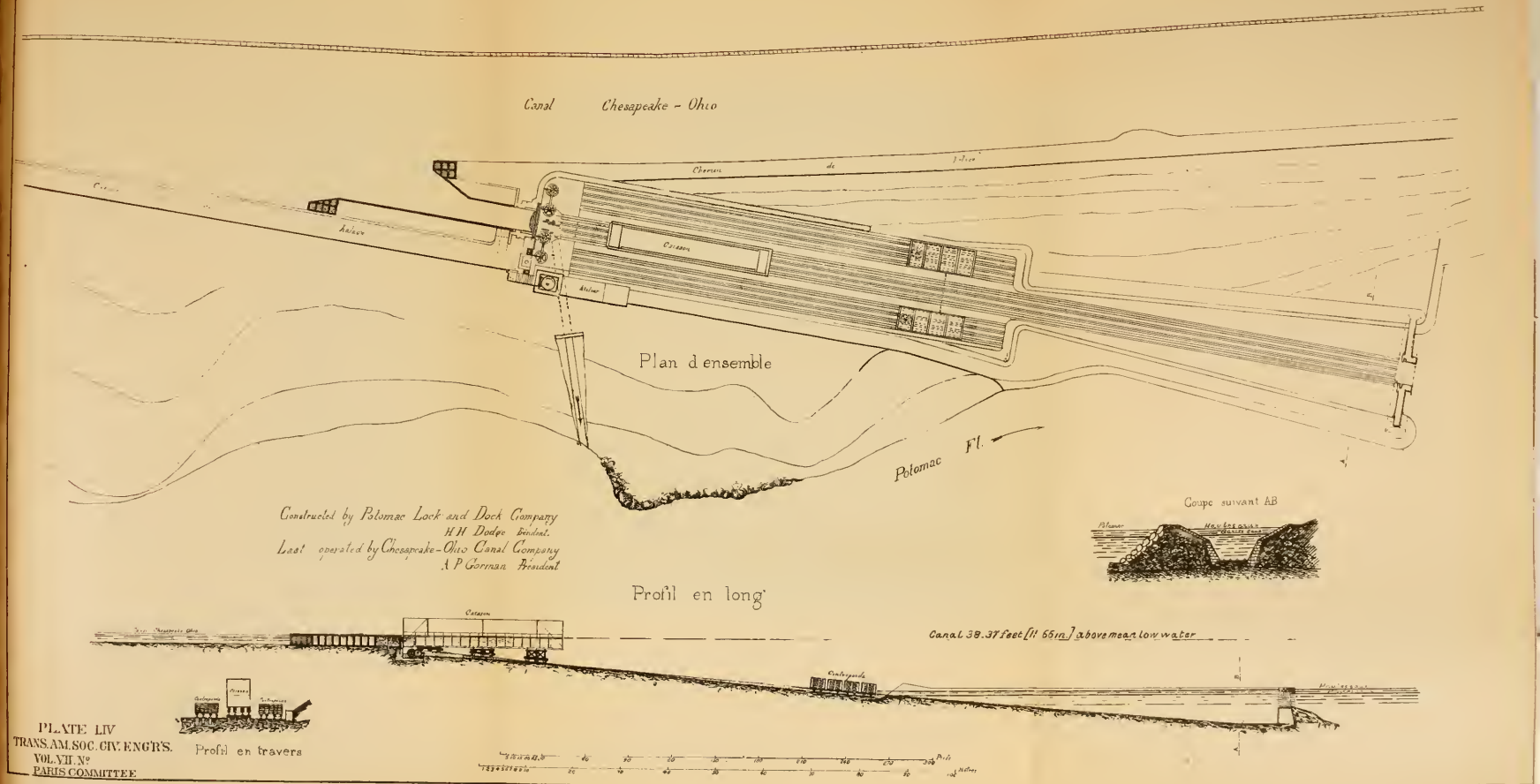


PLATE LIV
TRANS. AM. SOC. CIV. ENG'R'S.
VOL. VII. Nº
PARIS COMMITTEE

wheels, and is attached to the caisson ; by this arrangement the travel of the counterweights is but half that of the caisson.

The grade of the main track is one in twelve—that of the counterweight tracks, one in ten, and at the upper end, one in twenty. The grade was made lighter at the upper part to relieve the tension of the cables on the side of the counterweights when the caisson is immersed. On account of the variation of the level of the river surface, the diminished weight of the immersed caisson cannot be entirely compensated by this arrangement.

The descending boats are always loaded. Those ascending are empty.

The caisson descends full of water—it ascends full only to the bottom of valve openings in the rear gate.

The counterweights are a mean weight between the caisson full, descending, and the same ascending partly full. The descending side is therefore always the heavier, but the difference is not equal to the friction of the system.

The caisson is furnished with pawls dropping into the teeth of a ratchet rail on the track, and with brake shoes. Both are raised by hand and both may be tripped from the foot board of the caisson.

The maximum lift is 39.36 feet at extreme low tide. The minimum 36.75 feet at extreme high tide, or with a slight flood.

Length of caisson 108.25 feet, width in the clear 14.75 feet, draft of barges 5 feet. Load carried by barges 115 to 125 tons. Weight of caisson full, 360 tons, weight of each counterweight, 300 tons.

Each counterweight is furnished with pawls, which are raised and lowered by hand ; and with brake shoes which act automatically in case the main cable should break.

The caisson is held close to the head wall, while the gates are opened, by a hydraulic press worked from an accumulator. The press acts upon a wheel upon the main shaft, which when in gear turns the shaft, and through it the grooved wheels, to hold the caisson to the wall.

The rails are secured to wooden stringers, bolted to masonry walls, which are founded on the rock. The first rails were made of cast iron, because of the difficulty in getting ordinary rolled rails with a sufficiently broad flat head for the bearing of the wheel. They have been in great part replaced with steel rails, with a flat top.

The river wall was built in water 19½ to 23 feet deep by the system Beaudemoulin.

The work was constructed by the Potomac Lock and Dock Company, H. H. Dodge, President, and is leased and operated by the Chesapeake and Ohio Canal Company, A. P. Gorman, President.

GAS ENGINEERING.

To represent gas engineering, the Society was able to exhibit drawings and photographs of works and apparatus as employed in this country, which in some respects are novelties. The progress made in this branch of engineering is perhaps more marked than that of any other department. In fact, the beginning of the century knew no such business; fifty years ago New York city had no gas, and forty years since, all the gas supplied to the people of Boston was made in one iron retort.

The amount of capital now invested in this business in New York city and Brooklyn is represented by about thirty millions of dollars, and the number of works, great and small, throughout the country is about one thousand. The principal progress that has been made since the earlier days of gas lighting consists in the various scientific and mechanical means introduced for the proper treatment of the products derived from the destructive distillation of coal, so that while those portions that constitute the light-giving power of the gases evolved are carefully separated in a state of "purity" or freedom from the more deleterious elements, the other portions are still preserved, and handled in such a way as to be no longer "waste products," but sources of revenue in the production of articles of great value and usefulness in the arts. And while this country cannot claim so great a degree of perfection in this latter respect, viz., in the handling of residual products, as has been attained

abroad, the reason for this is to be found in the fact that the newness and fertility of our country does not afford the same market demand for these products.

The exhibits under this head consist of—

A detailed drawing of a multitubular condenser.

Photographs of a modification of the Livesey scrubber, with an automatic water distributing apparatus.

A complete drawing of the works of the New York Gas Light Company.

Photographs of the Nassau Works of Brooklyn, &c., &c., &c.

The multitubular condenser is an apparatus for condensing the tar from the gas. It consists of a cast iron box, or series of boxes, with two horizontal diaphragms or partitions—one near the top, the other near the bottom ; the upper and lower spaces thus formed are connected by cast iron pipes, usually about four inches in diameter, placed as closely together as possible. The middle space of the box is filled with water, which consequently surrounds the pipes above mentioned.

A series of boxes thus arranged are placed side by side, the gas is admitted into the lower space and passes up through the pipes to the upper space, from there it goes to the top space of the next box, down the pipes to the bottom space, thence into the next box, up the pipes, and so on, thus traveling up one set and down the other until the temperature of the gas is reduced sufficiently low by the water surrounding the pipes to cause the tar, &c., to be deposited in the lower space, from which the tar is run off into cisterns constructed for the purpose. The water surrounding the pipes is admitted from the end of the series of boxes opposite to that at which the gas enters, so that the water surrounding the pipes through which the gas first passes is the warmest (the heat having been acquired by the flow of gas), and that at the end where the gas leaves the condenser is the coolest. In this way the cooling of the gas goes on gradually, and is not too sudden in its change of temperature at any point, and the rapidity of cooling is easily controlled by regulating the amount of fresh water admitted to the condenser.

This form of condenser is largely used in this country, but is almost unknown in Europe, where, as a general thing, the temperature of the air is relied upon to cool the gas, which is passed through pipes out of doors for the purpose. The great advantage of the multitubular method

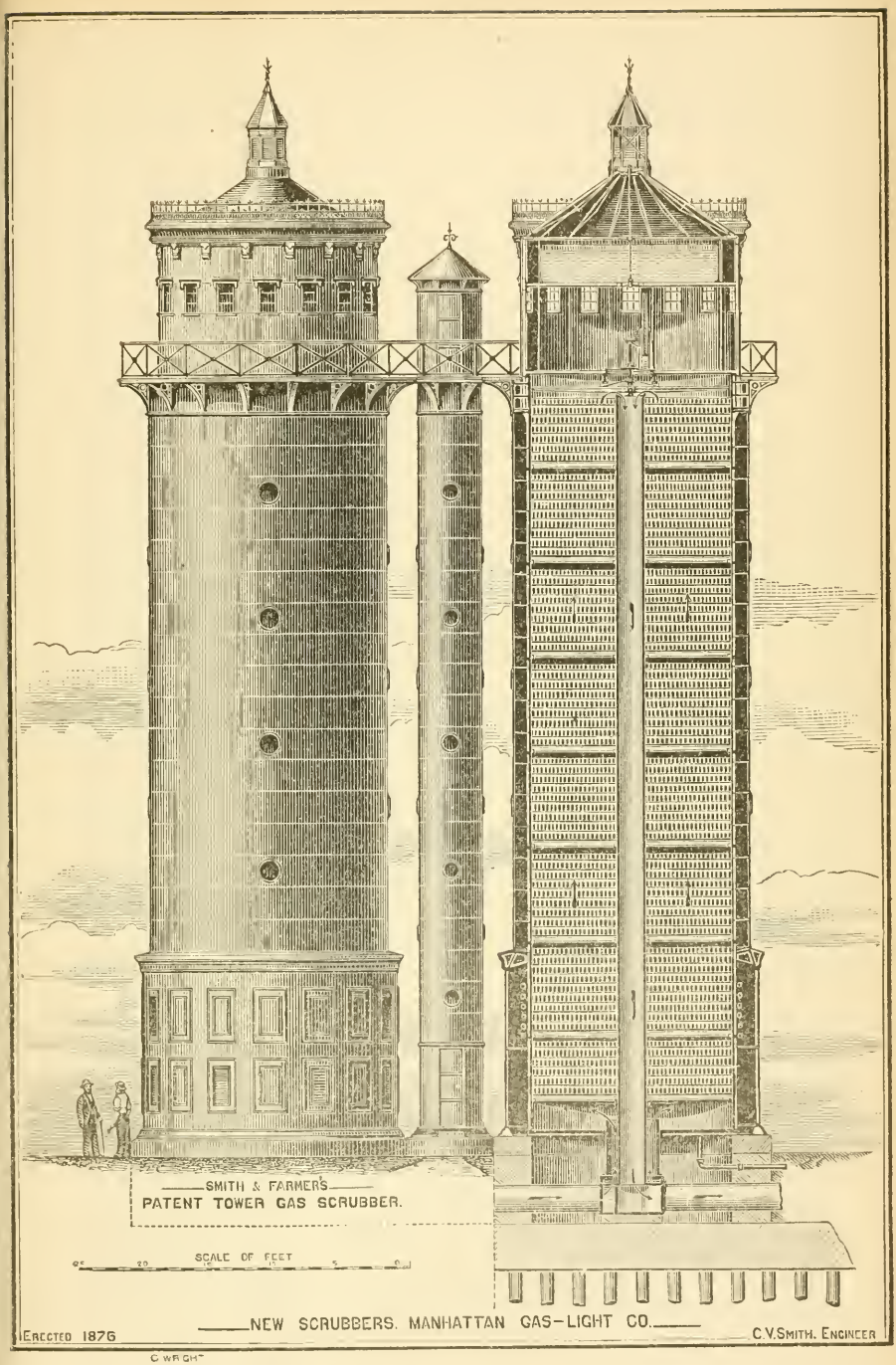
is the almost perfect control that it gives the manager over the rate of cooling. In submitting the drawings of this apparatus, the Society was enabled to present a novelty to the gas engineers of Europe.

Of the scrubbers of which photographs were submitted, and of which a drawing is shown on the opposite page (Plate LV.), the principal novelty consisted in the method of distributing the water. The object of the scrubber being to remove the ammonia from the gas by the use of water, by means of the distributer on the top the same water that is used to wash the gas is made to distribute itself by passing from a tank overhead, to which it had been previously pumped, over an overshot water wheel, which, by suitable gearing, turns two arms within the top of the scrubber, into which the water is conducted by a pipe leading from a trough under the water wheel. These arms are in the form of troughs, with notches cut in the edges, so that as the arms revolve horizontally the water drops on to the wooden slats with which the scrubber is filled. These slats being put in edgewise and kept a small distance apart, a very large area of wetted surface is presented to the gas as it passes through. The ammonia is taken up by the water, which passes off from the bottom as "ammoniacal liquor," and is collected in cisterns built for the purpose. The gas enters the scrubber at the bottom, and passing up to the top, is taken out by a central outlet pipe, which extends to the top. The gas on entering comes first in contact with the strongest liquor, and leaves through a spray of clean water. The strength of the liquor obtained from these scrubbers is from 16 to 20 ounces Twaddle. The quantity of water used is about one gallon to 1 000 feet of gas.

The photograph of the Providence Holder House shows one of the largest domes in the world.

The photographs of the works of the Nassau Company represent one of the most complete of our modern works.

The colored drawing of the plant of the New York Gas Light Company, aside from its accuracy of detail, shows the plan of the largest holders in the United States at the present day.


SMITH & FARMER'S
PATENT TOWER GAS SCRUBBER.
SCALE OF FEET
NEW SCRUBBERS. MANHATTAN GAS-LIGHT CO.
ERECTED 1876
C.V.SMITH. ENGINEER
C WRGHT

RAILROAD FORMS.

SUBJECTS EXHIBITED.

Album contributed by the Lake Shore & Michigan Railway Company.

This album is made up from the printed documents and blank forms used by that company in its several operating departments; beginning with a map showing the relation of its lines to the railways of the Northern and Western States, and another, showing, upon a larger scale, the country which they specially serve, as also the roads which contribute to, or compete for its traffic.

These are followed by an account of the growth of the present company through a consolidation of numerous smaller corporations, with a table of the earnings of all the corporations from their beginning. Othe tables give information of the financial condition of the company, and a complete account of its operations during the year 1877, with their results.

This is followed by the regulations printed for the employés of the company in the departments of the General Superintendent and Chief Engineer; comprising the general rules for the government of all, and the special rules for conductors, brakemen, newsboys, engineers, firemen, station agents and ticket agents; for the use of air brakes; for the care of injured persons; for telegraphers and for the baggage department; also, information for the public of the conditions upon which baggage will be carried.

The remainder of the Album is filled with the printed notices and blanks of each of the departments, arranged in groups according to the department by which they are used.

In this way, it was hoped to present a general view of the modes of advertising adopted by the passenger department; of the system of reports required by the General Superintendent, Chief Engineer, Auditor and other officers, from their subordinates; of the methods of billing freight over the railway from one station to another; from this railway to any other railway and to foreign parts, together with the reports of the tonnage and charges, which are made to the General Freight Agent. The blanks

used for reporting the mileage of its own cars upon its road, and the sheets upon which the miles run by each car are recorded; also, the method of reporting daily to other lines the miles run by their cars upon this road, are grouped under the head of Car Recorder's Department.

The various forms of passengers tickets used in through, way, excursion, emigrant, special and foreign business, are illustrated by samples of each kind; as, also, the manner in which sales of each are reported to the General Ticket Agent and Auditor.

In many, or perhaps in all their details, the forms and methods of each Department differ from those used by other railways of the United States; yet, by nearly all those railways the same general manner of carrying on their business is employed, so that this Album may be taken as a brief exposition of the way in which railway transportation is conducted in the States of the Union. As a rule, passengers and freights, traversing the main routes, are transported without change of cars, and are billed and ticketed through from the start to destination, so as to avoid delays.

It is the custom among the railways to accept the bills of lading and tickets issued by one road over any of the others. The manner in which contracts, shipments of freight, sales of tickets and divisions of receipts are reported, by one road to each of the others interested, is illustrated by the forms given in the Album.

The settlements of balance is effected between the roads acting as individuals (not through a clearing house), except in the case of what are known as Line Freights.

The Freight Lines of the United States are of two kinds, private and co-operative; and were established to facilitate the forwarding of goods over long distances, by acting as an intermediary for the shipper and for the many railway lines, over which the goods might have to pass to their destination.

The General Agencies of these lines, act as clearing houses between the several railway companies which they represent.

The co-operative lines are owned and operated by the railway companies over which they pass; the cars being furnished by each railway, its proportion of the general expenses being in the ratio of its length, to that of the whole distance traversed.

The private lines furnish cars and agencies upon a contract with the railway companies; many of the companies owning a part of the stock of the private lines.

Album contributed by the Providence & Stonington Steamship Company.

This album, like the preceding, contains samples of the company's business blanks, advertising posters, tickets, plans of the staterooms on the boats, and a full set of baggage checks. It also has a history of steamboat navigation on Long Island Sound from 1792 to the present time.

EAST RIVER BRIDGE.
SOCIÉTÉ AMÉRICAINE
INGÉNIEURS CIVILS
NEW-YORK
ndations & Maçonnerie
EFENSE
DE
UMER

GENERAL DESCRIPTION OF EXHIBIT.

The drawings and photographs are grouped in departments, and mounted on a structure erected for the purpose, where, together with the models and specimens, which are also conspicuously displayed, they may readily be seen and examined by all visitors to the Exposition. The tracings, albums, specifications, blank contracts, lithographs and other miscellaneous matter, not designed for general exhibition, are accessible to engineers and others who may desire to make special investigations.

The structure on which the drawings, photographs and models are exhibited was built by Messrs. Mead & Taft, of Cornwall-on-the-Hudson. All parts, except the interior frame, which is concealed by the drawings, are of American hard woods. It is an excellent example of first-class machine-made carpenter work, and in itself forms a good collection of native finishing woods.

This structure is 16 feet wide by 21 feet long. Its exterior surface furnishes six alcoves, each appropriated to a different department, while additional wall surface is provided in the interior, and a broad staircase leads to a platform above.

Four of the six alcoves are at the corners of the structure, and each of them affords three vertical wall spaces 3 feet wide by 5 feet high, two inclined spaces 3 feet square, and one smaller triangular space; the other two are in the middle of the long sides, and twice the size of the others. A copy of the only photograph of the Exhibit received from Paris is given herewith.

The six alcoves are appropriated to the following general departments: Foundations and Masonry, Bridge Superstructures, Hydraulic

Machinery, Inland Marine, Rolling Stock, River and Harbor Improvements.

The Society is greatly indebted to the Engineers Club of St. Louis, which undertook the task of preparing and collecting the drawings and photographs of the works which are represented from that section of the country. The promptness and care which these gentlemen showed in this connection did much to enable the Committee to make a satisfactory exhibit.

Besides the individual exhibitors hitherto mentioned, the Society is indebted to Mr. Frank Thomson, General Manager of the Pennsylvania Railroad Company for two very large photographs of locomotive and fully equipped passenger and express train on that road; to Mr. C. Vandervoort Smith, of the Manhattan Gas Company, Mr. T. K. Lees, of the New York Gas Company, Mr. J. H. Armington, of the Brooklyn Gas Company, Mr. F. S. Benson, of the Nassau Gas Company, and Mr. G. W. Dresser, of the *Gas Light Journal*, who contributed the exhibits referred to in the article on Gas Engineering; to Mr. C. C. Martin, for the photographs of the towers of the East River Bridge, in process of construction; to Mr. Moses Lane, for photographs of the Milwaukee pumping engine, and Milwaukee ship yards; to Mr. T. Guilford Smith, for harbor and lake photographs at Buffalo; to Mr. P. H. Dudley, for an automatic dynograph record; to Mr. S. H. Shreve, for a number of copies of his Treatise on the Strength of Bridges and Roofs; to Mr. T. S. Sedgwick, for his Treatise on Inclined Planes for Canals; to *The Railroad Gazette*, which has sent bound volumes of its paper and copies of its publications; to Mr. John Reid, of Paterson, N. J., for an album of photographs of bridges and other engineering works; to Mr. J. Mullen, of Lexington, Ky., for photographs of Ohio River Bridge; and to many other parties who have contributed tracings, photographs, photo-lithographs, chromos, engravings and water color sketches of bridges, roofs, buildings, rolling stock, machinery, steamboats, dredges, coal mines, and works in progress, as well as specifications for various engineering matters, reports of cities and boards of public works, and pamphlets explanatory of exhibits.

PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS.

(INSTITUTED 1852.)

VOL. IV.

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1878.

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— February 20th, 1878, Death of JOHN F. TRACY, Fellow A. S. C. E. announced and committee appointed to prepare memoir; committee on Paris Exhibit made report; Board of Direction made report; candidates declared elected; ballot upon adoption of a memorial to be again taken, 5.
— March 6th, 1878, Ballot upon amendment to By-Laws canvassed and amendment adopted; "Improvement of South Boston Flats," by EDWARD S. PHILBRICK read, 15.
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— April 3d, 1878, Thursday evenings attendance reported; committee on Paris Exhibit reports; memorial as to Triangulations of Coast Survey adopted, 31; ballots for membership canvassed; "The law of Tidal Currents in river harbors," by J. H. STRIEDINGER read; account of Hooghly Floating Bridge read, 22.
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— May 15th, 1878, "On the Theoretical Resistance of Railroad Curves," by SAMUEL WHINERY read, 37.
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— August 7th, 1878, Ballots for membership canvassed; resolution for appointment of committee on economy in use of steam referred to Board of Direction; death of C. RIDGELY SCHOTT announced and committee to prepare memoir appointed, 81.

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— October 2d, 1878, ballots for membership canvassed; ballot upon resolution to appoint committee as to maxumum economy in the use of steam canvassed; report of Board of Direction with proposed codification of Constitution and By-laws presented; amendments to Constitution and By-Laws presented, 90; paper upon tests of hydraulic cements and of bricks, by FRANCIS COLLINGWOOD read, 91.

— October 16th, 1878, "The Flow of Water, illustrated by Kutter's Diagram," by R. HERING read, 91.

— November 20th, 1878, "Submarine Telephoning," by CHARLES W. RAYMOND read; "The Permanent Way of Railways in Great Britam and Ireland, with especial reference to the use of timber preserved and unpreserved," by JOHN BOGART read, 131.

— December 4th, 1878, Ballots for membership canvassed; "The use of Compressed air in Tubular Foundations, and its application at South street Bridge, Philadelphia," by D. MCN. STAFFER read, 131.

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American Society of Civil Engineers.

PROCEEDINGS.

Vol. IV, January, 1878.

MINUTES OF MEETINGS.

(Abstract of such as may be of general interest to members.)

OF THE SOCIETY.

JANUARY 2D, 1878.—The Society met at 8 P. M., Vice-President Roberts in the chair. The Norman Medal was presented to William W. Maclay, and the Norman Prize of Books was presented to Julius H. Striedinger.

The following amendment to the By-Laws was moved by Mr. John Bogart, and seconded by Messrs. G. Leverich and George S. Greene, Jr.

By-Laws, Section 23, Sub-section 5, strike out the clause in brackets following this Sub-section, and leave the Sub-section so as to read as follows:

5th. A Junior shall be one who has had actual practice in some of the branches of civil, military, mining, or mechanical engineering, for not less than two years; or if a graduate of a scientific or collegiate institution, for not less than one year.

Under the rule this will be voted upon by letter-ballot.

The following resolution was passed:

Resolved, That the Secretary of the Society be requested to address a circular to the members of the Society, asking voluntary contributions for exhibition at the Paris Exposition, and inviting subscriptions of money to enable the Society to make a proper exhibition; and that he be requested to secure the necessary space for the use of this Society.

The following resolution was also passed:

Resolved. That a committee of three be appointed by the Chair to select some member of the Society to serve as sole Commissioner of the Society at the Paris Exposition—such selection to be reported for action at the next regular meeting of the Society.

Under this resolution, the following committee was appointed: Messrs. George S. Morison, Albert Fink, and John Bogart.

The result of the ballots on amendments to the Constitution and By-Laws was then declared as follows :

On the following amendment to the Constitution—

ARTICLE XIX.—For "two" insert "five" and for "thirty" insert "twenty-five". The article will then read :

All candidates for admission to the Society must file statements, by themselves, setting orth the grounds of their claim to be elected ; be proposed by at least five members of the Society, to whom they must be personally known, and a notification of the same sent to each member whose address is on record. Each proposition, with the names of the proposers, must be posted in some conspicuous place in the rooms of the Society for at least twenty-five days before being submitted to vote. All papers and applications shall be laid before the Board of Direction, and be reported upon previous to action by the Society.

There were 112 yeas, 8 nays, and no blanks. This amendment was declared adopted.

On the following amendment to the Constitution—

ARTICLE XX.—For "thirty" insert "twenty-five," and for last clause insert as below. The article will then read :

In elections for membership, of either class, members shall vote by letter, or by ballot in the usual way, and the result shall be announced at the next regular meeting held after twenty-five days have elapsed from the time of mailing the notification. Negative ballots exceeding five per cent. of the total number canvassed shall exclude.

There were 20 yeas, 97 nays, and 3 blanks. This amendment was declared lost.

On the following amendment to the Constitution—

ARTICLE XX.—In elections for membership of either class, members shall vote by letter or by ballot, in the usual way, and the result shall be announced at the next regular meeting held after thirty days have elapsed from the time of mailing the notification. Five or more ballots cast in the negative shall exclude. Members notified, but not responding, shall be classed as voting in the affirmative.

There were 92 yeas, 26 nays, and 2 blanks. This amendment was declared adopted.

On the following amendment to the Constitution—

ARTICLE XX.—For "three" insert "ten ;" the Article otherwise will read as the preceding.

There were 9 yeas, 100 nays, and 11 blanks. This amendment was declared lost.

On the following amendment to the Constitution—

ARTICLE —— (A new Article)—The Board of Direction may, for sufficient cause, excuse from payment of annual dues any member distinguished in his professional career, or who from ill health, advanced age, or other good reason assigned, has a scanty income ; and the board may remit the whole or part of assessments in arrears, or accept, in lieu thereof, desirable additions to the Library and Museum.

There were 41 yeas, 76 nays, and 3 blanks. This amendment was declared lost.

On the following amendment to the Constitution—

ARTICLE —— (A new Article)—Upon the written request of ten or more members that, for cause therein set forth, a person belonging to the Society be expelled, the Board of Direction shall consider the matter, and, if there be sufficient reason, shall advise the accused that his resignation will be accepted. He may, upon demand, receive a copy of the charges against him and present a written defense. Two months after such advice was given, the Board of

Direction shall finally consider the case, and, if resignation has not been tendered, or a satisfactory defense made, may then expel the accused. Such action shall be stated to him and the Society, and this shall be, in any event, the only public announcement of the matter.

There were 11 yeas, 103 nays, and 6 blanks. This amendment was declared lost.

On the following amendment to the Constitution—

ARTICLE ——(A new Article.) Upon the written request of ten or more members, that for cause therein set forth, a person belonging to the Society be expelled, the Board of Direction shall consider the matter, and if there is sufficient reason, shall advise the accused that his resignation will be accepted. He may, upon demand, receive a copy of the charges against him, and present a written defence. Two months after such advice was given, the Board of Direction shall finally consider the case, and if resignation has not been tendered or a satisfactory defence made, will then notify the member that he will be expelled in one month, unless he elects to appeal from this decision. Appeals will be submitted to the Society by letter ballot. In case no appeal be made, the Board of Direction will expel the member and notify him and the Society of the same, or of the action of the Society on appeal, and the above shall, in any event, be the only public announcement of the matter.

There were 98 yeas, 19 nays, and 3 blanks. This amendment was declared adopted.

On the following amendment to the Constitution—

ARTICLE XXII.—(To read.) Persons thus elected and duly qualified, who reside within fifty miles of the post office in the City of New York, shall be deemed Resident; and those who reside beyond this limit shall be deemed Non-Resident. The membership of any person shall begin on the day of his election.

There were 111 yeas, 4 nays, and 5 blanks. This amendment was declared adopted.

On the following amendment to the Constitution—

ARTICLE XXIX.—(To read.) Members, who become Residents or Non-Residents by removal into or beyond the limits prescribed in Article XXII., shall be subject to assessments in the class in which they were on the day of the annual meeting, as may appear upon the records of the Society, or by written notice to the Secretary.

There were 114 yeas, 2 nays, and 4 blanks. This amendment was declared adopted.

On the following amendment to the Constitution—

ARTICLE ——. (A new Article.) Members in arrears for more than one year's annual dues shall not be allowed to vote until such dues are paid.

There were 115 yeas, 4 nays, and 1 blank. This amendment was declared adopted.

On the following amendment to the By-Laws—

SECTION 30. (To read :)—Special committees to report upon engineering subjects, shall be authorized only by a majority of the votes cast by the Society, and in the following manner: Any resolution proposing such a committee shall be referred to the Board of Direction, which shall examine the same and report to the Society a concise statement of the argument against the appointment of such committee. The mover of the resolution under consideration shall be invited to present the arguments *for* the same, under a limit of occupying no more than one-half page of the printed proceedings in their presentation ; the same limit to obtain, also, in the case of the argument *against;* said invitation shall be extended to the mover, at least one month before the argument is needed to go upon the letter ballot, and if not furnished by that time, no argument for the resolution shall be presented. The statements of argument shall be printed, and issued to the Society with letter ballot ; or, if the Board fails to report within one month, the letter ballot shall be issued without comment ; or, the Society may vote

by ballot at the Annual Meeting, or in Annual Convention, upon such resolution within one month after it has been submitted to the Board of Direction. No mover of a resolution shall serve in the presentation of arguments *against* a resolution under this By-Law, while the resolution offered by him is pending a vote of the Society.

There were 77 yeas, 29 nays, and 14 blanks.

Upon the announcement of this ballot, the presiding officer decided that the 14 blank ballots ought not to be counted as part of the vote, and that the vote stood 77 yeas and 29 nays. An appeal was taken from this decision, and by vote the decision was reversed. This amendment was then declared lost.

JANUARY 16TH, 1878.—The Society met, Mr. Geo. S. Greene in the Chair. A paper entitled, "On Igniting Blasts by means of Electricity," by Julius H. Striedinger, was read.

FEBRUARY 6TH, 1878.—The Society met, Vice-President Roberts in the Chair. The Secretary, Mr. John Bogart, reported issue of circulars in reference to the Paris Exhibition, and also that on his application as directed by resolution of January 2d, a fair space in a good location had been assigned the Society by the Commissioner General of the United States for the Paris Exposition.

Mr. Geo. S. Morison, Chairman, presented the report of the Committee appointed January 2d, as follows:

The committee appointed to select a Commissioner to represent this Society at the Paris Exposition of 1878, begs leave to report:

That they have selected Mr. T. E. Sickels, as a gentleman eminently suitable for the position, and recommend that he be appointed Commissioner.

The Committee have had under consideration two possible classes of commissioners,

1st. A young man who would give his whole time to the care of the exhibit.

2d. An Engineer who could serve as representative of the Society, be able to introduce its members to foreign Engineers and secure means of access to foreign works, leaving details of the care of the exhibits to an assistant of his own selection.

The latter class has been preferred by the Committee, and therefore Mr. T. E. Sickels, who has exceptional advantages, is on intimate terms with the Commissioner General, and who expects to be in Paris during the continuance of the Exposition, has been selected.

The Committee also suggest the following resolution:

That a committee of three be appointed by the Chair to co-operate with the Commissioner in preparing a suitable exhibition on the part of the Society, such committee to be authorized to obtain for the purpose, by loan or gift, such drawings, models, photographs and other objects as shall, in their opinion, form a representative collection of American Engineering works; also to have the direction of the expenditure of the funds voluntarily contributed for these purposes.

The report of the Committee was accepted, its recommendations adopted and Mr. T. E. SICKELS was chosen as Commissioner to represent the Society at the Paris Exposition.

The resolution as recommended, was adopted, and the following Committee was appointed in accordance therewith:

GEO. S. MORISON,
EDWARD P. NORTH,
JOHN BOGART,

The tellers reported that upon the ballot upon the following resolution :

Resolved, That the further consideration of the metric system of weights and measures be indefinitely postponed,

There were 102 Ayes and 57 Noes. This resolution was declared adopted.

Upon the ballot on the question of adoption of the memorial in reference to the extension of the triangulations of the coast survey, and also upon the ballot for admission of new members, questions of order were raised and these ballots were referred to the Board of Direction. The Society adjourned to February 20th, at 8 P. M.

FEBRUARY 20TH, 1878.—A meeting of the Society adjourned from February 6th, was held at 8 P. M., Mr. R. H. Thurston in the Chair. The death, on February 13th, of Mr. John F. Tracy, Fellow of the Society, was announced by the Secretary, and W. Milnor Roberts and Milton Courtright were appointed a committee to prepare a memoir of the deceased.

The Committee on Exhibit at Paris reported that arrangements had been made for constructing a structure to be set in the Exposition building, so as to obtain ample wall space. Also that estimates of the necessary expenses of the Exhibit had been made and a circular letter prepared which was presented and read. The action of the Committee was approved.

The action of the Board of Direction upon the questions referred to it at meeting of Society of February 6th, was reported as follows :

1st. That the candidates voted for on ballot of February 6th, 1878, were duly elected, as follows : As members—C. Frank Allen ; C. G. Force, Jr. ; Charles P. Gilbert ; Edward Marsland; James C Post. As Juniors—Ira E. Clark ; Norman B. Kellogg ; Edward Prince.

2d. That as among the ballots cast upon the adoption of the memorial in reference to the triangulations of the Coast Survey, there were some admitted from members in arrears for more than one year's annual dues, and as the vote upon this question was within one of a tie vote, therefore the question of the adoption of that memorial should be again submitted to the Society.

OF THE BOARD OF DIRECTION.

JANUARY 2D, 1878.—The Board met and determined that an abstract of the discussion in reference to the metric system at the annual meeting and of letters since received upon that subject, should be prepared by the Secretary and sent out with the letter ballot upon the resolution indefinitely postponing the further consideration of the metric system. It was also determined that arguments should be prepared by a

committee and submitted with the letter ballot upon the adoption of the proposed memorial in reference to the extension of the triangulations of the United States Coast Survey. Applications for membership were considered.

JANUARY 16TH, 1878.—Applications for membership were considered.

FEBRUARY 6TH, 1878.—Applications for membership were considered.

FEBRUARY 18TH, 1878.—Applications for membership were considered. The subject of the ballots referred to the Board by the Society, February 6th, was considered, and action taken as follows: 1st. That all the candidates for membership on the ballot list voted for February 6th, 1878, were elected. 2d. That as among the ballots cast upon the adoption of the memorial in reference to the triangulations of the coast survey, there were some admitted from members in arrears for more than one year's annual dues, and as the vote upon this question was within one of a tie vote, therefore the question of the adoption of that memorial should be again submitted to the Society.

NOTES AND MEMORANDA.

EXPOSITION AT PARIS, 1878.

The following circular letter was prepared by the Committee on the Exhibit of the Society at Paris, and approved at the meeting of Society, February 20th, 1878:—

February 25th, 1878.

DEAR SIR—At the meeting of the Society, Jan. 2d, 1878, it was determined to take action towards securing for the Paris Exposition an exhibit of Engineering in the United States. The Secretary was directed to secure space, and a committee was appointed to suggest a commissioner to represent the Society. The committee found that a well known member of the Society, Mr. T. E. Sickels, intended to be in Paris during the Exposition, and had already been requested by the United States Commissioner-General to assist in having engineering well represented. The advantages of having, as the representative of the Society, an engineer of standing who would also be in close relations with the authorities at Paris, were apparent, and at the meeting of Feb. 6th Mr. Sickels was appointed Commissioner to represent the Society. The undersigned were appointed a committee to assist in securing a good exhibit, and to arrange in reference to the funds requisite to ensure success.

The space secured for the exhibit is 21 feet long and 16 feet wide, at the junction of two main aisles, with passage-way on all sides and the use of the wall surfaces back of this space. Upon this the committee purpose erecting a frame-work structure, so as to obtain all possible wall area, and to have a floor above for models, plans in portfolio, albums, &c. The divisions of the structure will be assigned to various departments, so that bridge superstructures, foundations, rolling stock, manufacture of steel and iron, hydraulic and steam machinery, pumping engines, turbines, improvement of rivers and harbors, inland navigation, canals, and if drawings are obtained, other branches of engineering may be intelligently represented in separate departments. Drawings of characteristic works actually constructed will be exhibited upon the walls, and additional drawings and photographs collected in portfolios. Some models will also be secured.

The committee has endeavored to keep the estimate of expenditures very low. The Commissioner serves without compensation. The structure will be framed here at small cost. We are assured of all possible facilities from

the Commissioner-General, who is personally anxious for the success of the exhibit. An attendant will be required, but it is thought that one may be found in Paris at moderate cost. It is believed that the entire expense can be brought within $1500. It is desirable that the amount subscribed should exceed this expense, so as to provide for printing and distributing to our members such information as may be collected at Paris. This committee is directed by the Society to appeal to its members for the requisite subscription. Business is not such as to warrant an expectation of many large subscriptions. But a number of moderate subscriptions, added to the larger ones of those members who can afford to make them, will assure success.

Will you kindly notify the committee if you can subscribe, and whether you have any plans or models you desire to exhibit?

GEO. S. MORISON,
EDWARD P. NORTH, } *Committee.*
JOHN BOGART,

METRIC SYSTEM OF WEIGHTS AND MEASURES.

In submitting to vote of the Society the following resolution, offered at the annual meeting, "Resolved, that the further consideration of the metric system of weights and measures be indefinitely postponed," the Board of Direction issued with the ballot the following abstract and letter :—

Abstract of the discussion at annual meeting, Nov. 7, 1877, following the presentation of the report of the Committee on Metric System of Weights and Measures.

The report of the committee was as follows:

G. LEVERICH, Esq., *Secretary American Society of Civil Engineers:*

DEAR SIR.—The Committee on Metric System of Weights and Measures respectfully ask leave to report at the next annual convention. Will you please present this report at the annual meeting?

Yours truly,
CLEMENS HERSCHEL,
Chairman for the Committee.

A member desired to know what duties were yet unperformed by this committee. It was appointed to prepare a memorial to present to Congress; it did prepare a memorial which was submitted to the Society and voted down; it is not to be supposed that the same memorial will be presented again at the next Convention.

Another member said that, as the form of memorial submitted by the committee had not been adopted, it was the duty of the committee to present another form of memorial. The rejection of the memorial was only, that its form was not satisfactory, but is no reflection on the diligence of the committee.

A motion that the committee be continued was lost.

It was then moved that another committee be appointed to carry out the wishes of the Society in framing a memorial to Congress on the adoption of a Metric System of Weights and Measures, in accordance with the provisions of the resolution adopted by this Society in appointing the former committee.

It was then suggested that if a committee be appointed for any such purpose, those members of the Society who are not in favor of a metrical system have an equal representation with those who are in favor of it.

A member said that there seemed to be a disposition among certain members to enforce one particular system upon the Society. He did not believe that the large majority of the Society would ever use the metric system. The Society voted to appoint the committee, with only one side of the argument presented to it. The papers in opposition to the metric system were not published until after the ballots were sent out. Two members of the committee withdrew because they were in a minority, and they did not wish to be represented on it. Afterwards there was a vote which showed it was not at all the sentiment of the Society that the metric system should be adopted. The Society voted as a matter of course for the appointment of a committee, but the Society voted against the resolution presented by that committee.

It was then moved that everything relating to the metric system or any other system of weights and measures be indefinitely postponed.

A member then said that, at the Convention of 1876 the following resolution was referred to the Board of Direction (Proc., vol. ii, p. 85):

"*Resolved*, That the American Society of Civil Engineers will further by all legitimate means the adoption of the metric standards in the Office of Weights and Measures at Washington, as the sole authorized standard of weights and measures in the United States; that the Chair appoint a committee of five to report to the Society a form of memorial to Congress in furtherance of the object expressed; and that the foregoing be submitted to the Society and voted on by letter ballot."

On December 6th, 1876 (Proc. vol. ii, p. 173), this resolution was directed to be submitted to letter ballot without comment. On Feb-

ruary 7th, 1877 (Proc., vol. iii, p. 7), the letter ballot was canvassed with the result of 138 ayes, 73 nays, and 20 blank. At the Convention of 1877 (Proc., vol. iii, pp. 47, 48, 52), the committee appointed under this resolution reported a form of memorial. That form of memorial was submitted to letter ballot and the ballot canvassed October 3d, 1877. This vote was not on the question whether a memorial should be presented at all but on the adoption of the form of memorial as presented by the committee. The statement of the argument against it, is printed in Proceedings for September, 1877 (vol. iii, p. 88). The most objectionable part of the memorial was as follows;

"The prayer of your memorialist, therefore, is that your honorable body may enact, that in every publication, report, advertisement and other official document issued by the Government, *only* the metric system of weights and measures shall be used on and after such date as your honorable body may deem the most advisable."

The ground taken was, that this was not what the committee was authorized to do, and the result of the ballot upon the adoption of this memorial was (Proc. vol. iii, p. 88), 18 ayes, 96 nays, and 5 blanks. This vote did not dissolve the committee; it merely expressed a disapproval of what they had submitted. It is the duty of the committee to present another form of memorial.

Another member said that, considering the question a very serious one, he thought that a more general expression of the views of the Society should be obtained than would be possible by a vote at this meeting. While it may be competent for action to be taken now, it would be wise to give all voting members of the Society an opportunity to express themselves upon it.

Another member said it seemed only a matter of fair play. The original resolution was sent out without comment, and before a number of papers discussing the matter had been published. Possibly, if the whole matter was again submitted to the Society the vote might be reversed. But the Society did, by a large majority, vote for the appointment of a committee, and no final action ought to be taken, except by the whole Society.

Another member said that, at the Convention of 1876, the subject was sent to the Board of Direction and to letter ballot, not by a vote of the Convention, but under the By-laws. No vote was taken at the Convention upon that subject. The mover of the resolution was allowed thirty minutes to advocate it: only one member was allowed to speak in opposition. The Society never voted approval of this system. The vote was only upon the appointment of a committee; that committee made a report, and that report was most emphatically voted down. A motion to continue the committee has to-day been lost. Another resolution was proposed at the Convention of 1877 (Proc. vol. iii, p. 48), for the appointment of a committee to consider and report upon what is the best system of weights and measures for the use of engineers in the United States. This member also said that while he considered the metric better than our present system, he was not assured that it was the best system. The Chairman of the Committee says he does not use it in his own office. Its use is principally by schoolmen and professors. It is based upon a wrong principle; the unit is too long. Nothing like our ten feet and hundred feet measures can be used. A better system can be devised. The Society ought not to commit itself to an imperfect system.

It was then ordered that the resolution be submitted to the Society for letter ballot.

The following letter from a member of the committee, is also presented:

"It seems to me that the proposed action would leave the Society in a worse position than it now occupies. It is now committed, by a standing notice printed in Proceedings, to the policy of writing in papers presented hereafter, 'weights and dimensions by the metric system, in connection with those of the system in general use' (Proc. vol. iii, p. 52). If we should never take another step, either forward or backward, this would be a nuisance. It is the policy of civilized nations to establish one system of weights and measures, and to prohibit the use of others. The United States, having two discordant standards now legal, has to decide which one it will ultimately use, and which abolish. In reply to a resolution of inquiry recently passed by the House of Representatives, the Heads of the Executive Departments have made reports as to the practicability of adopting the metric system exclusively and the time which should be allowed for its introduction; and it is publicly stated that the House Committee on Coinage, Weights and Measures will soon report a bill making the metric system obligatory in all governmental transactions. I think it eminently proper that the American Society of Civil Engineers should have an opinion on the question. The leading arguments on both sides have been presented in the debates we have already had, but there are those among us who might learn something from further discussion. The subject is of momentous importance, and the Society will make itself ridiculous if it undertakes to treat it with contempt."

PROPOSED MEMORIAL.

In submitting to vote the proposed memorial in relation to the extension of the triangulations of the United States Coast Survey (see Proceedings, November, 1877, vol. iii., page 127), the Board of Direction issued with the ballot the following arguments:—

Argument for Adoption.

The extensive and valuable work of the coast survey loses much of its practical utility unless its triangulations are made available in the manner provided for by previous Acts of Congress, and it is very poor economy to waste so much valuable and expensive work by failing to make the comparatively small appropriation needed to provide for its proper utilization.

The cost of obtaining the same results by independent State surveys would vastly exceed the amount of the appropriations called for, and states, although they have already paid their share of the heavy expense already incurred, will be discouraged from undertaking much-needed surveys if they are to be thus unnecessarily burdened.

No class of men are so well aware of the value of coast survey work for the purposes mentioned in the memorial as Civil Engineers, and there is accordingly a peculiar fitness in a testimonial to Congress to that effect from the American Society.

Argument against Adoption.

The views expressed in the memorial as to the propriety of utilizing to the fullest extent the valuable surveys made along our coast by the United States Government, seem to be unexceptionable; and probably few, if any, Civil Engineers, who have given the subject thought, would dissent therefrom.

As individuals probably a large majority of the American Society of Civil Engineers would be glad to see Congress act favorably in the premises; but it has not been, nor should it be the policy of this Society, as a body, associated for special purposes of mutual improvement to undertake to influence Congress by memorials. Its object might be misunderstood or misconstrued, and its legitimate influence in the country weakened.

PROPOSED AMENDMENT TO THE CONSTITUTION.

The following is a corrected reading of the amendment to the constitution offered by Mr. Francis Collingwood at the annual meeting, November 7th, 1877, and will take the place of the proposed amendment as printed in Proceedings for November, 1877, vol. iii., page 111 :—

Article — (a new article).— The Board of Direction may, for sufficient cause, excuse from payment of annual dues any member distinguished in his professional career and who, from ill health, advanced age, or other good reason assigned, is unable to pay such dues; and the Board may remit the whole, or part, of assessments in arrears, or accept in lieu thereof desirable additions to the library and museum.

LIST OF NEW BOOKS ON

ENGINEERING AND TECHNOLOGY.

Under this head will be announced new books on these and kindred subjects, which may be professionally useful to members of the Society.

Alphabets, Mediæval and Modern, Initials and Ornaments. E. G. Stagoll. London. 4to. illus. *Barnard.* 1s 6d.

Architects and Builders Pocket Book of Useful Memoranda and Prices. W. Young. London. 32mo. *Spon.* 4s. 6d.

Arithmetical Instruction, an Essay on Methods of —— ——. F. W. Bardwell. New York. 18mo. *Putnam.* $0 15.

Arts, The Decorative ——. William Morris. Boston. 16mo. *Roberts.* $0 30

Astronomy, Popular ——. Simon Newcomb, Professor U. S. Naval Observatory. New York. 8vo, illus. and maps. *Harpers.* $4 50.

Bridges, Iron Truss ——. Methods of Calculating Strains. Comparisons of Prominent Truss Bridges and new Formulas for Computations. Col. Wm. E. Merrill, U. S. Engineers. 3d ed rev. New York. 4to. illus. *Van Nostrand.* $5.00.

Cement, Science and Art of the Manufacture of Portland ——, with Observations on some of its constructive Applications. Henry Reid. New ed. London. 4to, illus. *Spons.* New York. $7.00.

Centennial Exhibition, The World's Fair. A critical account. Francis A. Walker, Chief of the Bureau of Awards. New York. 8vo. *Barnes & Co.* $0 75.

—— —— Official Awards and Claims of Exhibitors, and general reports of judges in the departments of Textile Materials, Fabrics and Machinery. Boston. 8vo. *National Asso. Wool Manufacturers.* $3.50.

Ceramic Art of Great Britain. Being a History of the Ancient and Modern Pottery and Porcelain Works of the Kingdom, and of their Productions. L. Jewitt. London. 2 vols. roy. 8vo illus. *Virtue.* 52s. 6d.

Chemistry, Elements of ——. Prof. Sidney A. Morton, Ohio Agricultural and Mechan-

ical College. Cincinnati. 12mo. illus. *Van Antwerp, Bragg & Co.* $1.10.

Chimneys, Boiler and Factory ——, their Draught Power and Stability; and on Lightning Conductors. Robert Wilson. London. Crown, 8vo. *Lockwood, Crosby & Co.* 3s. 6d.

Coal, A Practical Treatise on —— Mining. George G. Andre. London. 2 vols. roy. 4to, illus. *Spons.* New York. $28.00.

Coloring; A Grammar of ——. George A. Field. London. 12mo. (Weales Series.) *Lockwood.* 3s.

Contracts. The law of ——. John Wm. Smith. Sixth Am., from the Sixth London ed. Vincent T. Thompson. With Notes and References to both English and American cases by William Henry Rawle, and Additional Notes and References to recent American Decisions, by Hon. George Sharswood. Philadelphia. 8vo. *Johnson.* $5.50.

Design; Principles of Decorative ——. Christopher Dresser. London. Crown, 4to. illus., plates. *Cassell, Petter & Galpin.* New York. $3.50.

——— Studies in ——for Manufacturers, Architects, Builders, Designers, House Decorators, &c., being sixty original designs in colors, with descriptive letter press and treatise on principles of designing. Christopher Dresser. London. Folio, illus. *Cassell, Petter & Galpin. New York.* $25.00.

Dictionary of Manufactures, Mining, Machinery and Industrial Arts. George Dodd. New York. Crown, 8vo. *Van Nostrand.* $1.50.

Dictionary of Technology—in English, German and French. A. Tolhausen. Leipzig. *Tauchnitz.* (*B. Westermann, New York.*) $3.70.

Distillation. Destructive ——. A Manual of the paraffine, coal, tar, resin, oil, petroleum and kindred industries. E. J. Mills. London. 8vo. (*Van Nostrand, New York.*) $1.25.

Drawing, Industrial —— books. No. 3. Elements of decorative design; No. 5. Ornamental treatment of plant forms; No. 7. Principles of designing. Mark M. Maycock. Buffalo. Obl. 8vo. *M. Taylor.* Each part $0.25.

Engineering, Manual of Civil—. W. J. M. Rankine. 12th ed. revised by E. F. Bamber. London. Post 8vo, illus. *Griffin.* 16s.

Engineers, The boy—: What they did and how they did it, J. Larkin. London. Sq. 16mo. *Trubner.* 7s. 6d.

——— The boy—: What they did and how they did it. J. Larkin. New York. 8vo, illus. *Putnam.* $1.75.

———, Architects and Contractors' pocket book, 1878. London. 12mo *Lockwood.* 6s.

Excavation and Embankment. Formulæ for the calculation of—and for finding average haul. J. Woodbridge Davis. New York. 8vo. *Gilliss Bros.* $1.00.

Form, American—book, with forms for every State and Territory. J. R. Sayler. Cincinnati. 8vo. *R. Clarke.* $2.00.

Foundations. Jules Gaudard. Trans. by L. F. Vernon Harcourt. New York. *Van Nostrand's Science Series. No.* 34. $0.50.

Gas. Common Sense for gas users: a catechism of gas lighting. Robert Wilson. London. Crown 8vo, illus. *Lockwood. Crosby & Co.* 2s. 6d.

———, Engineers' and Superintendents' Almanac for 1878. New York. 16mo, tucks. *American Meter Co.* $2.00.

——— Manufacture. A practical treatise on the manufacture and distribution of Coal Gas. William Richards. London. Demy 4to, illus. plates. (*Spons. New York.*) $12.

Geology, Elements of—Jos. Le Conte. New York. 8vo. illus. *Appleton.* $4.00.

Geometry, Elements of—G. A. Wentworth. Boston. 12mo. illus. *Ginn & Heath.* $1.00.

Graphic Statics, Elements of—Karl Van Ott. Trans. by G. S. Clarke. (*Spons. New York.*) $2.

Heat, A practical treatise on—as applied to the useful arts, for use of Engineers, Architects, &c. Thos. Box. 2d ed. 8vo, illus. (*Spons. New York.*) $5.00.

——— The handbook of—. Lardner. New ed. enl. by B. Loewy. London. Post 8vo, illus. *Lockwood, Crosby & Co.* 6s.

Harvard examination papers. New ed. with papers for 1877. Boston. 12mo. *Ginn & Heath.* $1.50.

Hydraulic Tables for finding the mean velocity and discharge in open channels. Thomas Higham. Roy. 8vo. (*Spons. New York.*) $2.00.

Hydraulics. The new formula for mean velocity of discharge of rivers and canals. W. R. Kutter. Trans. by L. D'A. Jackson. London. 8vo. (*Spons. New York.*) $5.00.

Landscape Gardening, Practical——F. R. Elliott. Rochester. 8vo, illus. *D. M. Dewey.* $3.00.

Metals, The founding of—. Edward Kirk. 3d ed. New York. 8vo. *D. Williams.* $2.50.

Military Engineering. Instructions in——Vol. I, Part 1, Field defences. Compiled at the School of Military Engineering. Chatham. 2d ed. Post 8vo. *British Government Publication.* 3s. 6d.

Mineral Surveyor and Valuer's complete guide. W. Lintern. London. 12mo. (Weale's Series.) *Lockwood, Crosby & Co.* 3s. 6d.

Mineralogy. Part 1, Advanced Science Series. J. H. Collins. New York. 12mo. *Putnam.* $1.50.

Mining Machinery. A descriptive treatise on the machinery, tools and other appliances used in Mining. George G. André, in 12 parts. London. Roy. 4to, illus. (*Spons. New York.*) Each part $2.00.

Mines. Accidents in—their causes and prevention. A. Bagot. London. Post 8vo. *C. K. Paul & Co.* 6s.

Obelisks. Cleopatra's Needle, with notes on Egypt and Egyptian—. Erasmus Wilson. London. 8vo. *Brain.* 5s.

Painting. Neutral tint ——— with 24 plates from designs by R. P. Leitch. The Letterpress to each Plate contains Full Instructions to the Learner, and the Plates show the progress of the work through its different stages. Oblong 4to. *Cassell, Petter & Galpin, New York.* $2.50.

——— Sepia ——— with 24 Plates from Designs by R. P. Leitch. The Letterpress to each contains Full Instructions to the Learner, and the plates show the progress of the work through its different stages. Oblong 4to. *Cassell, Petter & Galpin, New York.* $2.50.

——— Water Color ———, By R. P. Leitch. With 24 Colored Plates, and Full Instructions to the Pupil as to the manner of Mixing and Applying the Colors. 2d ed. *Cassell, Petter & Galpin, New York,* $2.50.

Patent Office. Account of the Destruction by Fire of the North and West Halls of the Model Room in the United States Patent Office Building, Sept. 24, 1877. Together with a History of the Patent Office from 1790 to 1877. Boston. 8vo., illus. *A. Williams.* $0.50.

Pattern Maker's Assistant. With tables. Joshua Rose. New York, Crown 8vo, illus. *Van Nostrand.* $2.50.

Photographed Spectra. One hundred and thirty-six Photographs of Metallic, Gaseous and other Spectra, printed by the permanent Autotype Process. With Introduction, description of plates, and Index, and with an extra plate of the Solar Spectrum. J. Rand Capron. *Spons, New York.* $12.00.

Photography. A Treatise on ———. W. de W. Abney. New York. 12mo, illus. *Appleton.* $1.50.

Physiography. An Introduction to the Study of Nature. T. H. Huxley, F. R. S. New York. 12mo, illus. and plates. *Appleton.* $2.50.

Screw Cutting Tables for Engineers and Machinists. Lord Lindsay. London. 4to. *Spons.* 2s.

Screws. Theory of ———. A Study in the Dynamics of a Rigid Body. R. S. Ball. London. 8vo. *Simpkin,* 10s. 6d.

Slate Quarrying. A Treatise on ——— ——— Scientific, Practical and Commercial. D. C. Davis. London. 8vo. *Lockwood.* 6s.

Specifications and Contracts. A Manual of Engineering. ——— ——— ———. Lewis M. Haupt. Philadelphia. 8vo, illus. *T. M. Stoddart & Co.* $3.00.

Steam Engine. A practical treatise on the ——— ———. Containing plans and arrangements of details for fixed steam engines, with essays on the principles involved in design and construction. Arthur Rigg. Demy 4to, illus. and plates. *Spons, New York.* $17.00.

——— ———. Considered as a Heat Engine. A treatise on the theory of the Steam Engine. Jas. H. Cotterill. 8vo, illus. *Spons, New York.* $5.00.

Tables. Engineers, Contractors, and Surveyors' pocket table book. 10th ed. rev. J. M. Scribner, New York. 16mo. *Van Nostrand.* $1.50.

———. Engineers and Mechanics' Companion. With Weights, Measures, Roots, Areas, Mechanical Powers, Steam Engine, &c. 18th ed. rev. J. M. Scribner. New York. 16mo. *Van Nostrand.* $1.50.

Telephone. Researches in Electric Telephony, being a lecture delivered before the Society of Telegraph Engineers. By Prof. Alex. Graham Bell. Profusely illustrated. 8vo, paper. *Spons, New York.* $0.60.

Virginia. Physical Survey of ———. M. F. Maury. With notes and additions. Richmond, Va. 8vo, map. *Randolph & English.* $0.30.

Water Supply of Cities and Towns. William Humber. London. Imp. 4to, illus., plates. *Lockwood, Crosby & Co.* £6 6s.

Workshop Receipts. For the use of Manufacturers, Mechanics and Scientific Amateurs. Ernest Spon. Crown 8vo, illus. *Spons, New York.* $2.00.

ADDITIONS TO

LIBRARY AND MUSEUM.

From Administration des Ponts et Chaussées, Paris.

Annales des Ponts et Chaussées, November, 1877.

Annales des Ponts et Chaussées, December, 1877.

From C. F. Allen, Boston:

Report of Board of Water Commissioners of Newton, Mass., November 1, 1877. Boston.

From Phinehas Barnes, Plainfield, N. J.:

A Treatise on the Chemistry of Gold, Silver, Quicksilver, and Lead. Edward Price. San Francisco, 1860.

Perpetual Water Indicator and Steam Pressure Gauge. William C. Grimes. Philadelphia, 1858.

Report of the State Geologist on Metalliferous region bordering on Lake Superior. St. Paul, 1866

Report on the Hudson River Railroad. John B. Jervis. New York, 1846.

Report on Hoosac Tunnel and Troy and Greenfield Railroad, by the Joint Committee, 1866. Boston, 1867.

Silver Mining Regions of Colorado. J. P. Whitney, 1865.

The Steam Engine as it was and as it is. Hon. William H. Seward, 1853. Providence.

Glances at the Victoria Bridge and the men who Built it. Charles Legge. Montreal, 1860.

Specifications of Pumping Engines and Boilers. Chicago Water Works 1870.

From L. F. Beckwith, New York:

The Pictet Artificial Ice Company. New York, 1877.

From Gen. S. V. Benét, Chief of Ordnance, Washington:

Annual Report of Chief of Ordnance U. S. A. June 30, 1877. Washington.

From Robert Briggs, Philadelphia:

On the relation of Moisture in Air to Health and Comfort. Philadelphia, 1877. (Copies for distribution.)

From the Bureau of Education, Washington:

Circulars of Information of the Bureau. Nos. 1 and 2. Washington. 1877.

Contributions to the History of Medical Education and Medical Institutions in the United States. 1776–1876. Washington. 1877.

From Howard Fleming, New York:

Narrow Gauge Railways in America. Philadelphia. 1876.

From T. Higginbotham, Esq., Melbourne, Australia:

Report of Observations on Railways made during a tour in Europe and America, in 1874–5. T. Higginbotham. Melbourne. 1876.

From Gen. A. A. Humphreys, Chief of Engineers, Washington:

Report of Chief of Engineers on Patent Office fire. Washington. 1877.

Report of Engineers upon repavement of Pennsylvania Avenue. Washington. 1877.

United States Geological Exploration of the 40th parallel. Clarence King. Descriptive Geology by A. Hague and S. F. Emons. Washington. 1877.

From the Institution of Civil Engineers, London:

Proceedings at Sixtieth Annual Meeting. December 18, 1877. London.

From the Institution of Civil Engineers of Ireland, Dublin:

Transactions of the Institution. Vol. XI. Dublin. 1877.

From Charles Lagasse. Nivelles. Belgium:

Notice sur les dragues à mouvement discontinu en usage aux Etats-Unis d'Amerique. Ch. Lagasse. Bruxelles. 1877.

Notice sur l'explosion d'une Chaudiere rotative à la Societe des Papateries des Nivelles. Bruxelles. 1877.

L'explosion d'une mine à Hell-Gate aux Etats. unis d'Amerique. Ch. Lagasse. Bruxelles, 1877.

From the Louisville and Nashville Railroad Company:

Annual Report of the Company, 1876–7. Louisville. 1877.

From the Minister of Public Works, Mexico:

Annals of the Public Works of the Republic of Mexico. May to October, 1877. Mexico. 1877.

From E. Pontzen, Paris:

Die Bedeutung des Rostock Berliner Scheffahrtskanals. Morits Wiggers. Rostock. 1877.

XIII und XIV Jahresbericht des Vereins für Erdkunde zu Dresden. 1877.

From Messrs. Shedd & Sawyer, Boston:

Report of Water Commissioners of Newton, Mass., Nov. 1, 1877. Boston. 1877.

From S. H. Shreve, Morristown, N. J.:

Proceedings of Commissioners of Rapid Transit in the City of New York. July to December. 1875. New York. 1877.

From the Smithsonian Institute, Washington:

Annual Report of Board of Regents of the Smithsonian Institute. 1876. Washington. 1877.

Transactions of the Austrian Society of Engineers and Architects. May to September, 1877, incl. Vienna. 1877.

From R. H. Thurston, Hoboken, N. J.:

On a new type of Steam Engine, theoretically capable of utilizing the full mechanical equivalent of heat Energy. R. H. Thurston, Philadelphia. 1877.

From Welton and Bonnet, Waterbury, Conn.:

Eleventh Report of the Water Commissioners of the City of Waterbury. Hartford. 1877.

ANNOUNCEMENTS.

Members of the Society who expect to visit Europe during the present year, are requested to inform the Secretary as soon as possible of that fact, and also of the time when they purpose leaving and the probable length of their stay abroad.

The Tenth Annual Convention of the Society will be held in Boston about the middle of the month of June, 1878. The precise date and particulars will soon be announced.

The Journal of the Austrian Society of Engineers and Architects for December, 1877, publishes a review by Mr. C F. von Popp of the paper by Mr. Clinton B. Sears, on the Principles of Tidal Harbor Improvement as applied at Wilmington, California, (Transactions Vol V, No. CXXXI, page 388).

In the publication "Excerpt Minutes of Proceedings of the Institution of Civil Engineers Vol. LI, Session 1877-8, Edited by James Forrest, Secretary, abstracts of the following papers published in the Transactions of this Society are given:

Proportions of Eye-Bar Heads and Pins as determined by Experiment. by C. Shaler Smith. (Transactions, Vol. VI, No. CXLVII, page 263.)

Wing Dams in the Mississippi above the Falls of St. Anthony. by Edward P. North. (Transactions, Vol. VI, No. CXLVIII, page 268.)

Title Page and List of Contents of Volume VI of Transactions and Title Page and Index of Volume III of Proceedings are issued with this number.

The following resolution was adopted at the Ninth Annual Convention of the Society, and ordered printed regularly in the Society publications:

Whereas, the metric system of weights and measures is now extensively used abroad; and whereas, it is desirable that the relation of the units of differing systems be made familiar to all, by comparison:

Resolved, that members be requested, in papers hereafter presented to the Society, to write, in parenthesis, weights or dimen-

sions by the metric system in connection with those of the system in general use.

THE ATTENTION OF MEMBERS IS EXPRESSLY called to the following resolution, passed after the reading of the paper published in the present number of Transactions:—

Whereas, It has appeared in the discussion of the paper on cements, contributed by W. W. Maclay, that other members of the Society have data bearing on this subject, which is valuable and interesting, but which they may deem hardly extensive enough to form the subject of separate papers, and whereas, there is, doubtless, a large amount of such information in the possession of individual members of the Society;

Therefore Resolved, That the members of the Society be requested to communicate to the Secretary any unpublished information they may have on the subject of cements which they are willing to make public, the same to be edited by the Secretary and published by him in a single paper.

IN TRANSMITTING LETTER BALLOTS members of the Society are requested to conform in all respects with the printed regulations issued with the ballots. These regulations are frequently not complied with. Ballots are received without the signature of the member on the outer envelope, with initials instead of full signature or with other irregularities. When laid before the Society such irregular ballots have been thrown out and members sending them have lost their votes. The regulations seem to be as simple as possible to secure a fair secret ballot.

ILLUSTRATIONS OF PAPERS presented for publication should be distinctly drawn in *broad, sharp* lines, upon *white, smooth* (not "egg" or enamelled) paper, with perfectly (not glossy, or gray) *black* ink, to a scale twice or thrice greater than the print is to be: which in no case should require folding in more than one direction (*i. e.*, the depth of plate, as inserted in Transactions, should not exceed 7 inches). Shades are to be produced by variations in size and spacing of *black* lines; no brush work or colors are admissible. Unless figures and letters can be *well* put in, simply pencil them, leaving the engraver to insert them on the plate. Always put a lineal scale upon each drawing.

MEMBERS OF THE SOCIETY are requested to contribute papers on Engineering subjects, giving results of practice, or discussing pertinent theoretical questions; their comments upon papers published in Transactions are solicited, and they are urged to contribute from note-books and other records whatever may bear upon the subjects considered, or upon other practical topics. A list of subjects relating to the practice of engineering and its connection with kindred art and public affairs, on which papers are desired, may be found on page 51, vol. 1.

DONATIONS TO THE LIBRARY.—Members and others are asked to contribute regularly to the library of the Society, copies of government, municipal, railway, canal and other reports, specifications, profiles, maps, photographs and like matter, making up the record of engineering operations for the past or present, and to inform the Secretary where such may be had. Duplicate copies are desired, for transmission to foreign societies in return for works collected and sent to this library by them; also for exchange with members and others who wish complete sets referring to particular subjects. Donations of old or new reports or pamphlets which refer to or illustrate Engineering constructions or operations are particularly solicited. Many of these may be really of great importance as a part of the Library, and as possibly containing information which might not otherwise be preserved.

THE HOUSE OF THE SOCIETY is at 104 East Twentieth street, one door east from Fourth avenue, and near southwest corner of Gramercy Park. It is open from nine o'clock, A. M. to five o'clock P. M. each business day except Saturday, when it is closed at three o'clock P. M.

The Library and Conversation Rooms will also, for the present be open every *Thursday evening*, from 7½ to 10 P. M. Members are invited to avail themselves of the opportunities afforded on Thursday evenings both for consultation of books and periodicals and for conversation.

LIST OF MEMBERS.

ADDITIONS.

MEMBERS.

Date of Election.

ALLEN, C. FRANK.....Assistant Engineer Newton Water Works, 66 Vernon St., Boston, Mass. Feb. 6th, 1878.

Date of Election.

GILBERT, C. P. . . . . Civil Assistant Engineer, United States Engineer Office, 85 Washington Av., Detroit, Mich . . . . . Feb. 6th, 1878.

MARSLAND, EDWARD . . . . . Marine Engineer, Sing Sing, N. Y. . . " " "

JUNIOR.

CLARK, IRA E. . . . . City Engineers' Office, Cambridge, Mass . . . . . " " "

CHANGES AND CORRECTIONS.

MEMBERS.

CLARKE, FREDERICK W. . . . . Civil Engineer, Room 24, 80 Dearborn St., Chicago, Ill.

COOPER, THEODORE . . . . . Care Keystone Bridge Co., Pittsburg, Pa.

DARRACH, CHARLES G. . . . . 100 North 39th St., Philadelphia, Pa.

DAVIS, CHAS. E. L. B. . . . . Captain of Engineers U. S. A., P. O. Drawer 432, New Orleans, La.

FALCONNET, E. F. . . . . Engineer N. & T. R. R. Co., Lebanon, Tenn.

FARQUHAR, F. U. . . . . Maj. of Engineers U. S. A., Rock Island, Ill.

GOLAY, PHILIP . . . . . 307 Court St., Cincinnati, Ohio.

LATROBE, CHARLES H. . . . . 146 North Charles St., Baltimore, Md.

MCCLINTOCK, W. H. . . . . Asst. Eng. Louisville Water Co., Fair Grounds, Jefferson Co., Ky.

NICHOLS, O. F. . . . . Maderia & Mamoré Railway, care of P. & T. Collins, 207 Walnut Place, Philadelphia, Pa.

PARKHURST, H. W. . . . . Division Engineer, R. C. St. L. & C. R. R., Glasgow, Howard Co., Mo.

READ, ROBERT L. . . . . Civil Engineer, 57 West Third St., Cincinnati, Ohio.

SEARLES, WILLIAM H. . . . . Civil Engineer, Rochester, N. Y.

SEDGWICK, THOMAS S. . . . . Superintendent of Construction U. S. Court House and Post Office, Austin, Texas.

SMITH, C. SHALER . . . . . 215 Washington Ave., St. Louis, Mo.

STRIEDINGER, JULIUS H. . . . . 17 University Place, New York.

WURTELE, ARTHUR S. C. . . . . 115 West Eagle St., Buffalo, N. Y.

JUNIORS.

HORTON, SANFORD . . . . . Covington, Nebraska.

KNIGHT, WILLIAM B. . . . . Care of Panama R. R. Co., 7 Nassau St., New York.

LUCAS, D. JONES . . . . . Lock Box 133, Warren, Pa.

DECEASED.

TRACY, JOHN F. . . . . Fellow . . . . . February 13th, 1878.

American Society of Civil Engineers.

PROCEEDINGS.

Vol. IV, February, 1878.

MINUTES OF MEETINGS.

(Abstract of such as may be of general interest to members.)

OF THE SOCIETY.

March 6th, 1878.—The Society met at 8 p. m., Vice-President Roberts in the chair.

The ballot upon the following amendment to the By-Laws was canvassed :—

Section 23; Sub-Section 5th.—Strike out the explanatory clause in brackets, from the words "[The term" — — to "Associate is not]."

The Sub-Section will then read :—

5th.—A Junior shall be one who has had actual practice in some of the branches of civil, military, mining or mechanical engineering, for not less than two years; or if a graduate of a scientific or collegiate institution—for not less than one year.

Upon this there were : For the amendment, 75 votes, against the amendment, 7 votes. This amendment was thereupon declared adopted.

A paper by Edward S. Philbrick, entitled "The Improvement of the South Boston Flats by the Harbor Commissioners of the State of Massachusetts," was read by the Secretary.

March 20th, 1878.—The Society met at 8 p. m., Vice-President Fink in the chair. A paper by R. H. Thurston, entitled, "On a New Method of detecting overstrain in iron and other materials, and on its application in the investigation of the causes of accidents to bridges and other constructions," was read by the author, and discussed by him and Messrs. Collingwood, Emery, Haswell, Holley, Macdonald and Worthen.

OF THE BOARD OF DIRECTION.

March 6th, 1878.—Applications for membership were considered. Financial and other business transacted.

LIST OF NEW BOOKS ON

ENGINEERING AND TECHNOLOGY.

Under this head will be announced new books on these and kindred subjects, which may be professionally useful to members of the Society.

Aid Book to Engineering Enterprises abroad. Ewing Mathewson. 8vo. *Spons. New York.* $4.25.

Alphabets. Tompson's Roman ——, with scales and proportions. Also specimens of ornamental, distorted and perspective letters. New York. 12mo, illus. *F. W. Devoe & Co.* $0.75

Architecture, Scottish Woodwork of the Sixteenth and Seventeenth centuries. J. W. Small. Edinburgh. Folio, illus. *D. Douglas.* 84s.

—— Home Interiors. E. C. Gardner. Boston. *Houghton, Osgood & Co.* $1.50.

Armies, The —— of Asia and Europe, embracing official reports on the armies of Japan, China, India, Persia, Italy, Russia, Austria, Germany, France and England. Accompanied by letters descriptive of a journey from Japan to the Caucasus. Gen. Emery Upton, U. S. A. New York. 8vo. *Appleton.* $3.00.

Belting, a Treatise on the use of —— for the transmission of Power. John H. Cooper. Philadelphia. 8vo, illus. *Claxton, Remsen & Haefelfinger.* $3.50.

Blasting, Rock ——; a practical Treatise on the means employed in Blasting Rock for industrial purposes. Geo. G. André. London. 8vo, illus. Plates. *Spons. New York.* $4.25

Bridge, Kansas City ——, with an account of the regimen of the Missouri river, and a description of Methods used in founding in that river. O. Chanute and Geo. S. Morison. New York. 4to, illus. Plates. *Van Nostrand.* $6.00.

Capital, Conflicts of —— and Labor. Including chapters on the history of Guilds, Trades Unions, Apprentices, Technical Education, Intimidation and Picketing, Restraints on Trade, Strikes—their Objects, Aims, and Results, Trade Councils, Arbitration. Co-operation, Friendly Societies, the Labor Laws, &c. George Howell. London. Crown 8vo. *Chatto & Windus* 7s 6d.

Chemistry, a Treatise on ——. H. E. Roscoe and C. Schorlemmer, Professors of Chemistry in Owens College, Manchester, England. Volume I. The New Metallic Elements. New York. 8vo, illus. *Appleton.* $5.00.

—— The Chemist's Manual. A practical Treatise on Chemistry, including Qualitative and Quantitative Analysis, Stoichiometry, Blow-pipe Analysis, Mineralogy, Assaying, Toxicology, &c., &c. Henry A. Mott, Jr. New York. 8vo. *Van Nostrand.* $6.00.

—— Naquet's Legal ——. A Guide to the Detection of Poisons, Falsification of Writings, Adulteration of Alimentary and Pharmaceutical Substances, Analysis of Ashes, and Examination of Hair, Coins, Arms, and Stains, as applied to Chemical Jurisprudence, for the use of Chemists, Physicians, Lawyers, Pharmacists, and Experts. Translated from the French by J. P. Battershall. New York. 12mo. *Van Nostrand.* $2.00.

—— Qualitative Chemical Analysis. A Guide to the Practical Study of Chemistry, and in the work of Analysis. S. H. Douglas and A. B. Prescott. Second edition, rev. New York. 8vo. *Van Nostrand.* $3.50.

Dictionary, Brande's —— of Science, Literature and Art. Re-edited by the Rev. Sir G. W. Cox. Rev. ed. London. 3 vols. 8vo. *Longmans.* 63s.

Engineering, Notes on —— Construction. Embracing Discussions of the Principles involved, and Descriptions of the Material employed. J. E. Shields, C. E. New York. 12mo. *Van Nostrand.* $1.50.

Iron and Steel, Strength and Calculation of Dimensions of —— —— Constructions with reference to the latest Experiments. J. J. Weyrauch. New York. 12mo. Plates. *Van Nostrand.* $1 00.

Manufactures, The —— of Cincinnati, and their relation to the future progress of the city. S. D. Maxwell, Cincinnati. 8vo. *R. Clarke.* $0.25.

Manures, Artificial Manures: How to make, buy, value and use. A. Sibson. London. 8vo. *Rudgway.* 2s. 6d.

Mathematics, American journal of — — pure and applied. Ed. by I. I. Sylvester, W. E. Story, B. Peirce, S. Newcomb, and H. A. Rowland. Published under the auspices of the Johns Hopkins University. V. I, Pt. I, 4to, pp. 104. Baltimore. *B. Westerman & Co. New York.* Per vol., $5 00.

Matter and Motion, J. Clerk Maxwell. New York. 16mo. illus. *Van Nostrand's Science Series.* $0.50.

Mechanic, The Amateur Mechanic's Practical Hand-book. Describing the different tools required in the workshop, the uses of them and how to use them; also examples of different kinds of work, etc., with full descriptions and drawings. Arthur H. G. Hobson. Philadelphia. 16mo, cloth, illus. *Claxton, Remsen & Haeffelfinger.* $1.25.

Mechanical Powers, Hughes's Easy Lessons on the — —. With Copious Exercises by one of Her Majesty's Inspectors of Schools. London. 12mo. *Stewart.* 1s.

Ordnance, Woolwich System of Rifled ——. A contribution to the history of its invention. By its Inventor. London. 8vo. *Hodgson,* 1s.

Parks, Our parks to be or not to be: papers read before the New York Academy of Sciences, April 30, 1877, and February 1, 1878, by a physician. New York. 12mo. *Brentano.* $0.15.

—— Central Park Reports. 13 vols. half calf, extra. New York. *H. K. Van Sicklen.* $75.00.

Price Book. The Builder's and Contractor's — — for 1878. (Lockwood & Co.'s) Revised by Francis T. W. Miller, Architect and Surveyor. With Latest Prices up to present date. 12mo, half-bound, 4s.; limp cloth, 3s. 6d.

Printing, The invention of ——: a collection of facts and opinions descriptive of early prints and playing cards: the black-

books of the fifteenth century; the legend of Lourens Janszoon Coster of Harlem, and the work of John Guttenberg and his associates. Illus., with facsimiles of early types and wood-cuts, 2d ed., 8vo, pp. 556. Theo. L. De Vinne New York. *Francis Hart & Co.* $6.00.

Railways, Remunerative —— for new countries; with some account of the first railway in China. Richard C. Rapier. London. Cr. 4to, illus. and photos. *Spons, New York.* $6.00.

Sanitary Science, The future of — —. B. W. Richardson. London. 8vo. *Macmillan.* 1s.

—— Sewer Gas and how to keep it out of houses: A hand book on House drainage. 3d ed., 12mo. O. Reynolds, London. *Van Nostrand. New York.* $0.60.

—— Health and Healthy Homes: how to secure healthy and comfortable homes. London. 8vo. *Sanitary Engineering Co.* 6d.

Science Conferences, held in connection with the Special Loan Collection of Scientific Apparatus, at the South Kensington Museum, on Chemistry, Biology, Physical Geography, Geology, Mineralogy and Meteorology. By the most eminent English and Foreign Scientists, 12mo, cloth. New York. *Scribner, Welford & Armstrong.* $2 25.

Science Primers: Chemistry, H. E. Roscoe; Physics, Balfour Stewart; Physical Geography, A. Geikie; Geology, A. Geikie; Physiology, M. Foster; Astronomy, J. N. Lockyer; Botany, J. D. Hooker; Logic, W. S. Jevons; Inventional Geometry, W. G. Spencer; Pianoforte, Franklin Taylor. New York. 18mo. *Appletons.* Each, $0.45.

Star-finder, or Planisphere with movable horizon: arranged by G. W. Plympton. New York. In colors, on card-board. *Van Nostrand.* $1.00.

Steam Jacket, The abuse of the — — practically considered. W. Fletcher. London. Crown 8vo. *Spons, New York.* $1.25.

Telephone, All about the — and Phonograph. Containing descriptions of Bell's and Dolbear's Telephones and Edison's Phonograph; History of the Discovery, Details of Construction, and interesting experiments. London. 12mo. *Ward & Lock.* 1s.

—— The: Its History, Construction, Principles, and Uses, with definite Instructions on the Making of Telephones, by which Failure is impossible, and to which is added a chapter on the Phonograph. S. Garner. London. 12mo. *Simpkin.* 1s.

ADDITIONS TO

LIBRARY AND MUSEUM.

From the Association of Civil Engineers of Portugal:

Review of Public Works and Mines, October, 1877. Lisbon.

From S. Thayer Abert, Washington:

Report upon improvement of Rivers and Harbors in District of Columbia, Virginia and North Carolina. Washington. 1877.

From Administration des Ponts et Chaussees, Paris:

Annales des Ponts et Chassées, January, 1878.

From John W. Bacon, Danbury, Conn.:

Twenty-fifth Annual Report of the Railroad Commissioners of Connecticut. Hartford. 1878.

Fifth Annual Report of the Railroad and Warehouse Commission of Illinois. Springfield. 1875.

Sixth Annual Report of the Railroad and Warehouse Commission of Illinois. Springfield. 1876.

Third Annual Report of the Commissioner of Railroads of Michigan. Lansing. 1874.

Fifth Annual Report of the Commissioner of Railroads of Michigan. Lansing. 1876.

Third Annual Report of the Railroad Commissioners of Wisconsin. Madison. 1876.

From Gen. J. G. Barnard, New York:

Investigation of Accidents on Railroads. J. G. Barnard. Washington. 1877.

Report by Capt. M. R. Brown, relating to work at South Pass, Mississippi River. Jan. 29th, 1878. Washington. 1878.

From Board of Health of City of Brooklyn:

Report of the Board, 1875-6. Brooklyn. 1877.

From Board of Railroad Commissions of Massachusetts:

Ninth Annual Report of the Board. Boston. 1878.

From G. Bouscaren, Cincinnati:

Report on progress and construction of the Cincinnati Southern Railway. December 1st, 1877. Cincinnati. 1878.

From Capt. M. R. Brown, New Orleans:

Eighth Report upon improvement of the South Pass, Mississippi River. December 15th, 1877. Washington. 1878.

From E. S. Chesbrough, Chicago:

Report of Commissioners for Testing the West Side Pumping Engines. April 25th, 1877. Chicago. 1877.

From the Department of the Interior;

Contributions to the history of Medical Education and Medical Institutions in the United States. Special report. N. S. Davis. Washington. 1877.

From the Engineers Club of Philadelphia:

Description of the Wilcox Spouting Well. Charles A. Ashburner. Philadelphia. 1877.

Oil Well Records, selected from collections of J. F. Caul. Survey of Oil District of Pennsylvania. J. P. Lesley. Philadelphia. 1877.

Silurian Plants. Leo Lesquereux. Philadelphia. 1877.

From Walton W. Evans, New York:

American Engines and Farlie Engines compared. Walton W. Evans. New York. 1877.

From the Franklin Institute, Philadelphia:

Journal for March, 1878.

From Charles H. Haswell, New York;

Piece of White Marble perforated by the Boring Sponge while sunk in the Brig Grecian on the Long Island Coast. 1870.

From Geo. Howland, Jr., New Bedford, Mass:

Eighth Annual Report of the Acushnet Water Board. New Bedford. December. 1877.

From Gen. A. A. Humphreys, Washington:

Map of the Battle-field of Gettysburg, in three parts.

Report of the Chief of Engineers, U. S. A. Parts 1 and 2 for 1877. A. A. Humphreys. Washington.

Physics and Hydraulics of the Mississippi; reply to criticisms made by Dr. Hagen, Director General of Public Works of Prussia. A. A. Humphreys.

Report of the Commissioners to examine the Moline Water Power 1877.

Report of Capt. M. R. Brown relating to South Pass, Mississippi River. 1878.

Report of Major G. Weitzel on the Louisville and Portland Canal, for the year 1877.

Information relating to improvement of the Providence River and Narraganset Bay. Rhode Island. January 31st, 1878.

From William R. Hutton, Baltimore:

Photolithographs and specifications of Moveable Dam, designed for Kanawha River Improvement.

From the Institution of Civil Engineers, London:

Abstracts of Papers in Foreign Transactions and Periodicals.

Description of Coffer dams used at Dublin, Birkenhead and Hull. Wm. James Doherty. London. 1877

From the Institution of Mechanical Engineers, London:

Proceedings of the Institute. November. 1877.

From the Iron and Steel Institute, London:

Journal of the Institute. 1877.

From G. Leverich, Brooklyn:

Municipal Reports of San Francisco for 1876–7.

From Mansfield Merriman, New Haven:

A list of writings relating to the method of least squares, with historical and critical notes. Mansfield Merriman. New Haven. 1878.

From the North of England Institute of Mining and Mechanical Engineers, Newcastle upon-Tyne:

Transactions of the Institute, vol. xxvi, 1876–7. Transactions of the Institute, September and October, 1877.

From William H. Paine, New York:

Specifications for Cast Iron Wire Rope Sockets for the suspenders of the East River Bridge, 1877.

Specifications for Granite Face, Arch, and other stone for approaches for East River Bridge, 1877.

Specifications for Steel Cable Wire for East River Bridge, 1877.

Specifications for Wrought Iron Cable Bands and Bolts for Suspenders of East River Bridge, 1877.

From E. S. Philbrick, Boston:

Annual Report of Board of Harbor Commissioners. Boston. 1877.

From Ernest Pontzeu, Paris, France:

Thirteen Lithographed Working Drawings of Structures at Vienna Exhibition. R. v. Waldheim. Vienna.

From E. Prince, Quincy, Ill.:

Revised List of Water Works in the United States and Canada, so far as known. E. Prince. 1877.

From William Rotch, Fall River, Mass.:

Report of the Watuppa Water Board. Fall River Water Works. January 1st, 1878.

From the Royal United Service Institution, London:

Journal of the Institution. No. xciii. 1877.

From Franz Rziha, Vienna:

Eisenbahn Unter-und-Oberbau. 2d Part. Franz Rziha. Vienna. 1877.

ANNOUNCEMENTS.

The Tenth Annual Convention of the Society will be held at Boston, beginning Tuesday, June 18th, 1878.

Sessions for the consideration of professional subjects, and one for the transaction of business will be held.

When determined by the Local Committee, the arrangements in detail will be announced.

The following is a list of topics to be considered with reference to papers published in Transactions during the preceding year.

Bridges.

CXL. Approximate determination of stresses in the Eye-Bar Head. William H. Burr.

CXLIV and CXLIX. Relative quantities of material in bridges of different kinds, of various heights. Charles E. Emery.

CXLVII. Proportion of Eye-Bar Heads and Pins as determined by experiment. C. Shaler Smith.

Boilers.

CXLI. Connected-Arc Marine Boilers, a demonstration of the principles of their construction. Charles E. Emery.

—— Discussions on above paper. J. Foster Flagg. Vol. VI., page 294.

Cements.

CLII. Notes and Experiments on the use and testing of Portland Cement. William W. Maclay.

DAMS.

CXLVIII. Wing Dams in the Mississippi above the Falls of St. Anthony. EDWARD P. NORTH.

HYDRAULICS.

CXXXIX. The Consumption and Waste of Water delivered by Public Works. JAMES H. HARLOW.

CXLV. The flow of water in open channels. THEODORE G. ELLIS.

CLIV. A peculiar case of failure in a water main. D. McN. STAUFFER.

—— Discussion on above paper. Vol. VII, page 15.

MASONRY.

CLI. Nomenclature of Building stones and stone Masonry. J. JAMES R. CROES, WILLIAM E. MERRILL and EDGAR B. VAN WINKLE.

MINES AND BLASTING.

CXLII. On the simultaneous ignition of thousands of mines and the most advantageous grouping of fuses. JULIUS H. STRIEDINGER.

CLIII. On igniting blasts by means of electricity. JULIUS H. STRIEDINGER.

PRESERVATION OF TIMBER.

—— Discussion on this subject. Vol. VI, page 189.

RIVERS AND HARBORS.

CXLIII. Improvement of Entrance to Galveston Harbor. CHARLES W. HOWELL.

CLV. The Improvement of the South Boston Flats. EDWARD S. PHILBRICK.

—— Discussion on Levees as a system for reclaiming low lands. J. FOSTER FLAGG. Vol. VI, page 305.

SURVEYS.

CXXXVIII. Co-ordinate Surveying. HENRY F. WALLING.

CXLVI. A novel railroad survey. THOMAS S. HARDEE.

CL. Description of survey for determining the slope of water surface in the Erie Canal. WILLIAM H. SEARLES.

In addition to the above papers, it is expected that the following subjects will be presented by papers printed previous to the date of the Convention, or read at its meeting.

Dams across Water Courses. WILLIAM J. McALPINE.

A new method of detecting overstrain in iron and other metals, and its application in the investigation of the causes of accidents to bridges and other constructions. ROBERT H. THURSTON.

The law of Tidal Currents. J. H. STRIEDINGER.

The South Pass Jetties; descriptive and incidental notes and memoranda. E. L. CORTHELL.

Construction and operation of the Incline Plane Railroad at Madison, Ind. M. J. BECKER.

Reminiscences and experiences of early engineering operations on railroads, with especial reference to steep inclines.

No. 1, W. MILNOR ROBERTS.
No. 2, WILLIAM J. McALPINE.

Resistances on Railway Curves. S. WHINERY.

Steam engine economy. A uniform basis for comparison. CHARLES E. EMERY.

Agricultural Drainage. ED. N. KIRK TALCOTT.

A graphic method of representing railroad accounts. CHARLES LATIMER.

Science, old and new. W. MILNOR ROBERTS.

Members of the Society are earnestly requested to furnish information or memoranda upon any of the subjects referred to. They are also invited and expected to take part in the discussions either in person or by sending to the Secretary notes for presentation.

In either case, it will assist the Committee in arranging the details for sessions of the Convention, if members expecting to take part in the discussions, will notify the Secretary at once to that effect.

THE ANNUAL MEETING of the American Institute of Mining Engineers will be held at Chattanooga, Tennessee, beginning Wednesday, May 22d, 1878.

MEMBERS WHO desire to secure complete sets of the Transactions of the Society are requested to send to the Secretary a list of the papers which are needed to fill up their sets. Some of the earlier papers are out of print. If orders are received for a sufficient number to warrant the expense, a reprint will be made.

THE HOUSE OF THE SOCIETY is at 104 East Twentieth street, one door east from Fourth avenue, and near southwest corner of Gramercy Park. It is open from nine o'clock. A. M. to five o'clock P. M. each business day except Saturday, when it is closed at three o'clock P. M.

The Library and Conversation Rooms will also, for the present be open every *Thursday evening*, from 7½ to 10 P. M. Members are invited to avail themselves of the opportunities afforded on Thursday evenings both for consultation of books and periodicals and for conversation.

Members of the Society who expect to visit Europe during the present year, are requested to inform the Secretary as soon as possible of that fact, and also of the time when they purpose leaving and the probable length of their stay abroad.

The following resolution was adopted at the Ninth Annual Convention of the Society and ordered printed regularly in the Society publications :

Whereas, the metric system of weights and measures is now extensively used abroad ; and whereas, it is desirable that the relation of the units of differing systems be made familiar to all, by comparison :

Resolved, That Members be requested, in papers hereafter presented to the Society to write, in parenthesis, weights or dimensions by the metric system in connection with those of the system in general use.

LIST OF MEMBERS.

ADDITIONS.

MEMBERS.

Date of Election.

NOBLE, ALFRED .....(Junior to Member) Asst. U. S. Engineer, Sault St. Marie, Mich.....April 3, 1878.

POST, JAMES C.....Captain of Engineers U. S. A., P. O. Box 266, Savannah, Ga.....Feb. 6, 1878.

JUNIORS.

HAYES, EDMUND .....Care of Morison, Field & Co., Engineers and Bridge Builders, Buffalo, N. Y.....March 6, 1878.

KELLOGG, NORMAN B.....Care of Fox & Kellogg, 530 California St., San Francisco, Cal.,.....Feb. 6, 1878.

PRINCE, EDWARD.....Hotel de Boston, 22 Louis le Grande, Paris, France..... " " "

CHANGES AND CORRECTIONS.

MEMBERS.

ALDRICH, JAMES C.....51 East Twentieth St., New York.

BAXTER, GEORGE S.....Greenwich, Conn.

BUELL, RICHARD H.....Room 47, 206 Broadway, New York.

FINK, RUDOLPH.....Asst. Supt. W. C., Virginia, Midland and G. S. Railroad, Alexandria, Va.

PETTIT, ROBERT E.. .....Asst. Engineer of Maintenance of Way, Penna. R. R., Union Depot, Pittsburgh, Pa.

SEARLES, WILLIAM H.....Civil Engineer, Room 57, Coal and Iron Exchange, New York.

JUNIORS.

HORTON, SANFORD,.....A. T. & S. F. R. R. Rocky Fora, Colorado.

TASKER, CHARLES A .....Civil Engineer and Surveyor, 180 West 4th St., Cincinnati, Ohio.

ASSOCIATE.

FORD, ARTHUR L.....Care of Garvalena y Ca. Caibarien, Cuba.

RESIGNED.

SANDBERG, CHRISTER P ....Member.. .....April 2, 1878.

American Society of Civil Engineers.

PROCEEDINGS.

Vol. IV, March, 1878.

MINUTES OF MEETINGS.

(Abstract of such as may be of general interest to members.)

OF THE SOCIETY.

April 3d, 1878.—The Society met at 8 p. m., Vice-President Roberts in the Chair. The Secretary reported that there had been an attendance of members at the rooms on each Thursday evening while they had been open, and it was resolved that the Library and Conversation Room should be kept open for the present and until further action on each Thursday evening from 7½ to 10 o'clock.

Mr. E. P. North, on behalf of the Committee on Exhibit at Paris, reported progress in the collection of material for such exhibit.

The ballot upon the adoption of the following memorial was canvassed :—

To the Honorable the Senate and House of Representatives of the United States in Congress assembled :

The American Society of Civil Engineers respectfully represents to your honorable bodies, that the triangulation of the United States Coast Survey, wherever it extends, affords a convenient and accurate basis for the location of roads, railroads and public works of all kinds, as well as for topographical and other surveys ; a basis which for precision and completeness is otherwise practically unattainable.

And the said Society, according their hearty approval of the United States laws, whereby the Coast Survey Department is authorized to extend its triangulations over States where scientific surveys are ordered by the State Legislatures, respectfully petitions your honorable bodies to make the necessary appropriations for continuing such triangulations as may be called for under the said laws, whereby the valuable work of the Coast Survey may be more fully utilized, to the great advantage of all portions of the country.

Upon this there were :—

For adoption, 73 votes ; against adoption, 66 votes. The memorial was thereupon declared adopted.

On motion, it was ordered that two copies of the memorial be engrossed, signed by the President and Secretary, and forwarded, one

to the Senate and one to the House of Representatives of the United States Congress.

The ballot upon admission to membership was canvassed, and the following were declared elected :—

As Members, O. L. Glover, of Lima, Peru, and Alfred Noble, of Detroit, Mich. (elected Junior February 10, 1875) ; as Junior, Edmund Hayes of Buffalo, N. Y.

A paper by Julius H. Striedinger, entitled "The Law of Tidal Currents in River Harbors," suggested by the paper on Improvements in Boston Harbor, was read by the author, and the subject discussed by Messrs. Collingwood, Haswell, W. J. McAlpine, and Roberts.

Mr. Bogart read from advance sheet of the Transactions of the Institution of Civil Engineers an account of the plan and construction of the Hooghly floating bridge in India.

April 17th, 1878.—The Society met at 8 p. m,, Vice-President Roberts in the Chair.

A paper by M. J. Becker, entitled "The Construction, Machinery and Operation of the Incline Plane Railroad at Madison, Ind.," was read by the Secretary. The subject was discussed and illustrated by Messrs. Chanute, Forney, William J. McAlpine, Roberts, Yardley and others.

The Society then adjourned, and on invitation, through Mr. William J. McAlpine, proceeded to the rooms of Mr. Johnson, who exhibited to the Society the construction and operation of the Edison speaking phonograph.

OF THE BOARD OF DIRECTION.

April 3d, 1878.—Applications for membership were considered. Appropriations were made. Questions of copyright were considered.

NOTES AND MEMORANDA.

United States Board to Test Iron, Steel and other Metals.—The attention of members of the Society is called to the following resolutions which were adopted at the last annual convention. The Committee of the Society upon the same subject urges upon all interested in the important work undertaken by this Board the fact that action in accordance with these resolutions must be taken at once to be of any avail. The Board must soon pass out of existence, unless further legislation is had.

Resolutions adopted at the 9th Annual Convention of the American Society of Civil Engineers :

"Whereas, in 1872, a committee of members of the American Society of Civil Engineers was appointed to take into account and to ascertain the best way of establishing a Board for the testing of such metals and alloys as form parts of the structures and machines required for use by the citizens of this country ; and

"Whereas, under this appointment, the committee proceeded in its labors so far as to obtain favorable action from the Congress of the United States, by a law authorizing the creation of a Board for the purpose of making such tests, and appropriating money to be expended therefor as well as in purchase of suitable machinery ; and

"Whereas, at a late session of Congress a law was passed, whereby said Board would cease to exist upon the expenditure of the money then appropriated ; be it

"Resolved, that this Society deems the tests proposed to be made, to be of national importance, and therefore asks that so much of the Sundry Civil Appropriation Bill, passed by Congress, as provides that the Board to test iron, steel and other metals, shall be discontinued when the money appropriated for its use shall have been expended, be repealed ; that the unexpended balance to the credit of the Board be re-appropriated, and that such further appropriation made be for the use of the Board as may be needed to complete the investigations undertaken—the sum required for the coming year being $40,000.

"Resolved, that each member of this Society be urged to use such influence as he may possess, to obtain favorable and immediate action by the Congress of the United States in furtherance of the objects here prayed for.

"Resolved, that the above resolutions be printed, and several copies furnished to each member of this Society, to be used by him in promoting the object sought ; and that reports of their action in the matter be made by each to the Secretary, giving names of representatives in Congress who have been addressed or seen on the subject."

NOTES OF MEETINGS.

A portfolio of a number of the original drawings of the first construction of the Philadelphia & Reading Railroad was sometime since presented to the Society by Mr. MONCURE ROBINSON, Honorary Member of the Society.* Extracts from the letter of Mr. Robinson sent with the portfolio, from the pamphlets which accompanied it and from the remarks made by W. MILNOR ROBERTS, at the time of the presentation are appended.

From the letter of Mr. MONCURE ROBINSON to Vice-President Roberts :

" * * * I am gratified to learn that you and Mr. Bogart think the plans of works on the Philadelphia & Reading Railroad will be interesting to many of our members, and I will take great pleasure in forwarding them. I will enclose with them a short report made to the Board of Directors in December, 1839, after *the first trial* of the Gowan and Marx and an account by Mr. Nicolls, the superintendent of the road of her *first regular performance* in February, 1840. I will add to them an address by Professor R. E. Rogers to the Franklin Institute in 1874, in the appendix to which you will find some extracts from publications of the period contemporary with the Gowan and Marx, showing the sensation made in Europe as well as in the United States by her performance. To this was due the invitation given Messrs. Eastwick and Harrison to visit St. Petersburg to make a contract for building the locomotives and other machinery for the St. Petersburg & Moscow Railroad, a contract which Mr. Harrison has often said to me was the foundation of the large fortunes made there by himself and his copartners. * * *"

From a report, dated Philadelphia, December 10th, 1839, made to the Directors of the Philadelphia & Reading Railroad Company by Messrs. Moncure Robinson and Wirt Robinson, Engineers of the Company :

"The undersigned are gratified in being enabled to report that the line of railroad between this city and Reading was on Thursday last opened for transportation. The Company's engine, the Gowan and Marx, on that day left Reading with a train of eighty cars, conveying, with other articles,

1,635 barrels of flour,
73¼ tons of blooms,
6 tons of coal,
2 hogsheads of whiskey,
60 persons.

The weight of the train, exclusive of the engine and tender, being 368 tons and the net load conveyed 240 tons.

The failure of one of the water pipes of the engine arrested the train after the lapse of an hour, in which time it had progressed twelve miles from Reading, and made it necessary to await the arrival of another engine, the Delaware. By this engine the whole train was first pushed four miles to a sideling at Pottstown and thence drawn on twenty-four miles to Norristown.

The whole weight of the Delaware, including fuel and water is ten and a quarter tons, and of the Gowan and Marx ten and seven-tenths tons.

It is hoped that this performance of engines of lighter dimensions than those now gene-

* See Proceedings, Vol. III, page 136, December, 1877.

rally ordered for heavy transportation will satisfy such of the stockholders as have hitherto been sceptical that the results anticipated by the undersigned will be at least realized, and that the load of an engine from the coal mines to the city will not be less than the amount (150 tons) estimated in their report of September, 1838. If this be so, there can be no room for doubt that the cost of transportation estimated in that report (52¾ cents per ton), will not be exceeded. This results, on the largest estimates of the expenses of a train, as unavoidably, from the amount of the load conveyed as the latter does from the graduation of the road.

The board will now probably be better satisfied than ever that the plan of improvement they have adopted was the only proper one for the objects they had in view. If instead of a graduation, the worst case of which is a *level*, undulations not exceeding thirty feet to a mile had been admitted, the load of the engine would have been but little more than one-third of its present load, and the cost of transportation would have been increased in nearly a corresponding ratio. While the first cost of the road has been somewhat greater on the plan adopted, the cost of transportation has been reduced very nearly to its minimum. The company has thereby insured large profits on articles which can bear the customary rates of railroad transportation, and more or less profit on every article brought on their improvement, and which can be transported at all in any other way."

"The undersigned have given much attention to the description of engines most judicious for your road. Among those in general use hitherto some (the English pattern) possessed the advantage of great adhesion, but without the requisite facility in turning curves. Others with this last advantage had the weight of about half the engine only on their driving wheels, their adhesion not only being diminished in proportion, but the weight on each driving wheel being still so great as rapidly to wear out the tires of the wheels, and to produce unnecessary injury to the rails. In addition to these disadvantages in most of our engines in ordinary use, it was essential to the plan of engine for our road that it should be as well as possible adapted to the use of anthracite coal, and to slow motion. The result of the attention given by us to this subject, has so far been most satisfactory. The engine, the 'Gowan and Marx,' above mentioned as the one used on the occasion of the opening of the road for transportation, is geared for slow motion (having but three feet three inch driving wheel), and a a velocity of from eight to ten miles per hour, her draft and generation of steam with anthracite coal, appear to us as perfect as in any locomotive that we know of. With the advantage of a truck for turning curves, she has three-fourths of her weight thrown on four instead of two driving wheels, giving her thereby a large amount of adhesion, but with the weight so divided as to be but little injurious to the tire of the wheel or the road. We are not without hopes that, aided by the suggestions of her ingenious builders, Messrs. Eastwick and Harrison, of this city, and our other experienced manufacturers we may be enabled to attain the whole adhesion of the engine without giving up the guide truck, and to divide the weight equally on all the wheels of the engine; points essential to obtaining at slow velocities, the maximum useful effect of the engine, and to diminish the wear and tear, both of engines and the road. In the mean time, it will be gratifying to the Board to know that we are in possession of two plans of engine for burning anthracite coal, that of the Gowan and Marx above described, and that adopted on the Baltimore and Ohio Railroad, which will realize all that it was ever expected their road would perform, and far transcend all that was promised at its commencement, and that any farther improvements in the plan of locomotive adapted to it, will only add still further to its useful effect, and reduce still further in the wear and tear of engines and the road; adding, of course, in a corresponding ratio, to the value of the work."*

From a report made by G. N. Nicolls, Superintendent Transportation, P. and R. R. R., dated Reading, February 24th, 1840:

"Statement of the performance of the locomotive engine Gowan and Marx, built by Messrs. Eastwick and Harrison, Philadelphia, on the Philadelphia and Reading Railroad, with a train of one hundred and one loaded cars, February 20th, 1840.

"Gross weight of train, including cars and freight, but not including engine or tender, 423 tons of 2 240 lbs.

Net weight of freight, 268½ tons of 2 240 lbs.

The freight consisted of—2 002 barrels of flour, 82 do. whiskey, 459 kegs of nails, 19 tons of bar iron, 22 hhds. of meal, 5 do.

* Included in this report is an estimate for an increased supply of rolling stock, which gives as cost of locomotives $7.500 each; of coal cars $270 each, and of ordinary freight cars $250 each.

whiskey, 4 do. oil, and sundry other articles, making a total of 268½ tons.

Distance from Reading to the foot of the Inclined plane on the Columbia Railroad 54½ miles. Running time of the engine with train, five hours thirty-three minutes; rate 9.82 miles per hour. Coal consumed, red ash, anthracite, from Schuylkill county, 5 600 lbs. Water evaporated, 2 774 gallons.

Grades of Road.

The total fall from Reading to the point where the train was stopped near the Columbia Railroad is 214.5 feet, being an average fall of 3.94 feet per mile. There is *no ascending grade* from Reading to the Columbia Railroad, with the exception of about 2 100 feet at its lower termination, graded at 26.4 feet per mile, upon which grade the train was stopped; the other grades vary from 19 to 15 feet per mile; there are only three miles graded at 18 feet and one at 19 feet per mile.

The total length of *dead level* line from Reading to the Columbia Railroad is 27 miles and 4 200 feet; of this the longest level is 9 miles and 1 500 feet long, between Norristown and the inclined plane; the others vary from 1 550 feet to 4 miles and 1 600 feet in length.

State of the Track.

Owing to the frost coming out of the ground at this season, the track was in worse order than at any other time of the year; this, however, did not materially affect the performance of the engine, as the embankments were all in nearly as good order as at other times; and at comparatively few points in the deep cut, was the track sufficiently out of line or level to offer increased resistance to the train.

The superstructure of the road consists of a T rail, 45 lbs. to the yard, laid upon sills 7 feet long and 7 by 8 inches square, 3 feet 1½ inches apart from centre to centre, and laid on broken stone.

State of the Rails.

For the first twenty miles the rails were in very bad order, the morning was cloudy, and a fog of the previous night had left sufficient moisture on the surface of the rails to diminish considerably the adhesion of the engine; for the remainder of the distance the weather was clear and the rails in good order.

Working of the Engine.

On three different occasions the engine started the whole train on a dead level, and when on a dry rail, without the wheels slipping.

The steam ranged from 80 lbs. to 130 lbs. per square inch, to which latter pressure the safety valve was screwed down.

The draught of the engine was created by the escape steam passing into, and from, a tubed exhaust box,—no other draft was used while running; at the water stations "Reilly's patent fan" was used when fresh coal was thrown on the fire, but at no other time.

The speed of the train was noted when passing through some curves of 819 feet radius on the 9 mile level, and found to be 9.8 miles per hour: on a straight line on the same level the engine attained a speed of 10.5 miles per hour.

So little was the engine affected by her performance on the 20th, that on the 23d she drew, on her return trip, 88 burden cars, 9 of which were loaded, and a locomotive engine, making a gross weight of 163 tons of 2 240 lbs., not including engine or tender, up a grade of 18.4 feet per mile. The train had a strong head wind against it during the whole trip, which, owing to its length, 1 206 feet, was sensibly felt at some exposed points of the road, and must have proportionably affected the power of the engine.

Weight and Dimensions of the Engine "Gowan and Marx."

Weight when empty 21 640 lbs. In running order, with fuel and water, 24 660 lbs., on four driving wheels in running order, or with water, fuel, and two men, 18 260 lbs. Cylinders 12⅔ by 16 inch stroke; 8 wheels, 4 of which are driving wheels, coupled, 3 feet 4 inches diameter; truck wheels 2 feet 6 inches diameter.;

The weight of the burden cars averaged from 1.5 to 1.65 tons, of 2 240 lbs. each; they were all 4 wheeled—wheels 3 feet diameter, and 4 feet 6 inches apart from centre to centre.

The above performance, of an 11 ton engine, is believed to exceed any on record in this or any other country."

From the remarks made by Mr. Milnor Roberts at the time of the presentation to the Society of the original drawings of works on the Reading Railroad:

In regard to the locomotive "Gowan and Marx," to which Mr. Robinson refers in his letter, and upon the performance of which Mr. Nicolls, at that time Superintendent of Transportation on the Reading Railroad, made his report in February, 1840, allow me to mention briefly some of the principal features of the road, the engine and its performance.

I recollect very well the sensation it created at the time both in this country and in Europe, as showing a material advance in loco-

motive construction. Previously, most of our locomotives had but two driving wheels, and their normal power of hauling was very much less than that exhibited by the Gowan and Marx.

The Reading Railroad had been very carefully and judiciously located by Mr. Robinson, its Chief Engineer, so as to present only descending or level grades from the coal region to Philadelphia, in the Schuylkill valley. There is one level of nine miles. The aggregate of the levels between Reading and Philadelphia is 27 miles, being about half of the distance. The residue has grades not exceeding 19 feet per mile; the whole distance, 54½ miles, averaging 3.94 feet per mile.

The real test was upon the 9 mile level, where the engine pulled the train through some curves of 819 feet radius at the rate of 9.8 miles per hour; and on a straight line of 10.5 miles per hour.

The train conisted of 101 four-wheeled cars, which weighed 154½ tons, of 2 240 lbs. (average weight of single car, 1.53 tons). The freight weighed 268½ tons, of 2 240 lbs. (average load per car, 2.66 tons). Total weight of train, exclusive of engine and tender, 423 tons of 2 240 lbs.; being about 39 times the weight of the locomotive, which was 11 tons.

The weight of the locomotive, when empty, 21 640 lbs. In running order, with fuel and water, 24 660 lbs. Weight on the four drivers, in running order, with water, fuel and two men, 18 260 lbs.

Cylinders 12⅔ inches by 16 inch stroke; 8 wheels, four of which were driving wheels, coupled, 3 feet 4 inches diameter; truck wheels, 2½ feet diameter.

The 4 wheeled cars had wheels 3 feet diameter, 4 feet 6 inches apart, from centre to centre.

Track laid with T rail, 45 lbs. per yard; gauge 4 feet 8½ inches.

The engine started the whole train on a level.

The steam ranged from 80 lbs. to 130 lbs. The draft of the fire was created by the escape steam passing into and from a tubed exhaust box. "Reilly's patent fan" was used when fresh coal was thrown on the fire, but at no other time.

The concluding remark of Mr. Nicolls report is, "The above performance of an 11 ton engine, is believed to exceed any on record in this or any other country." The date of this performance was February 24, 1840; almost 38 years ago.

Many changes, and numerous improvements have been made during these 38 years, in the construction and use of American railroads, locomotives and cars; and the capital invested in some of our most important roads is, in some cases, ten, fifteen, and even twenty times more than it was originally, The business also has been immensely augmented: though not proportionally with the augmented capital. The weight of the rail has been increased about 50 per cent., the weight of the empty car, upon 4 wheels, instead of being only 3 360 lbs., is at least two and a-half times as much, or, say 8 400 lbs., while the freight now carried is little more than the weight of the car, whilst in 1840, the car carried one and three-fourths times its weight. At the present day, if the passenger cars and sleepers, and cattle cars are taken into the account, the roads actually carry little, if any, more than the weight of the cars.

Locomotives weighing four times as much as the Gowan and Marx, cannot pull four times the amount of gross load pulled by that engine; much less can they transport four times her net load of freight.

Allowing 8 tons (of 2 240 lbs.) for the weight of a car, and 10 tons (of 2 240 lbs.) for the load of each car, it would require 212 cars, weighing 1 696 tons, to carry 2 120 tons of load; the total weight being 3 816 tons.

The performance of a 44 ton engine of the present day, might possibly be about half of this.

That is, if it be assumed that an engine might now pull a gross weight of 1 908 tons, it would convey but 848 tons of freight; or 4½ times the gross weight of the Gowan and Marx train, could show only 3⅓ times the freight that was carried on that train.

A battle has been raging for some years between armor plates on one side, and penetrating projectiles on the other; and the question may be asked, whether there is not another engineering battle now going on, between the weight and material of the rails, to withstand, and the weight and power of the locomotives and trains to destroy. In both cases, large sums are needed to carry out the experiments. It is a question, whether in the grandeur of certain things, we may not have passed the economical point.

An occasional reference to the railroad experience of forty years ago, may serve to show that some practical mechanical knowledge then existed, and that it was applied with good results.

I can state as within my own experience in the Alleghany Portage Railroad, Pennsylvania, in 1834, that there were performances of locomotives built by Wm. Norris, of Philadelphia,

in running over smooth rails up inclines of over 500 feet per mile; and one of his engines at one time conveyed a passenger car, with 50 passengers in it, up an incline of 422 feet per mile, at the rate of ten miles per hour.

THE FOLLOWING LETTER has been received from the *Verein Deutscher Ingenieure* (Society of German Engineers):

To the American Society of Civil Engineers:

In the expectation that many of the American engineers who may visit the Exposition at Paris, will feel an interest in the industries of Germany, which, as is known, will not be represented in Paris, and thinking that they may desire on this occasion to visit the factories and works of Germany, the *Verein Deutscher Ingenieure* remembering most gratefully the very kind and hospitable reception enjoyed by German engineers at the time of the Exposition at Philadelphia, offers most heartily a cordial welcome to its American colleagues, and desires to render all possible service to them.

We have therefore the honor, in the name of the Verein, to invite the members of the American Society of Civil Engineers or such other American Engineers as may be introduced by the Society, to visit the various industrial districts of Germany, and we add herewith a list of persons who have themselves offered to assist by information and introductions, such visitors from the United States as may apply to them.

With high esteem, in the name of the *Verein Deutscher Ingenieure*,

FR. EULER,
President,
Director of the Iron Works,
Kaiserlauten.
Prof. Dr. F. GRASHOF,
Director, Carlsruhe.

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Ingenieur Gotth, Sachsenber, Rosslau a, d. Elbe.

9. BERLIN AND VICINITY.

Geh. Rath Professor Reuleaux, Geh. Oberbaurath Schönfelder, Geh. Bergrath Dr. Wedding, Berlin.
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12. BAVARIA.

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C. Linde, Professor am Polytechnicum, München.

Zemann, Redacteur von Dingler's Polytechnichem Journal, Augsburg.

A. Frommel, Gerant der Spinnerei und Weberei, Augsburg.

G. Ultsch, Professor der Kgl. Industrieschule, Nürnberg.

Hilpert, Director der Machinenbau-Gesellschaft, Nürnberg.

Professor Dr. von Wagner, Würzburg.

Noll, Director der Waggonfabrik, Würzburg.

13. Baden.

Professor Dr. Meidinger, Vorstand der Landesgewerbehalle in Carlsruhe.

14. Palatinate—Saarbrücken,

Dingler, Machenenfabrikant in Zweibrücken.

Ingenieur Kauffer, firma: Eisenwerk Kaiserslauten, Kaiserslauten.

Hans Schon, firma: Kamgarnspinnerei, Kaiserslauten.

Marzall, Eisenbahnwerkmeister, Korn, Lederfabrikant, Saarbrücken.

Ingenieur Brandt, firma: Dingler, Karcher & Cie., in St. Johann.

Bergrath Hoernecke, Dudweiler.

Burbache Hütte, bei Saarbrücken.

Dillinger Hüttenwerke, Saarlouis.

15. Middle Rhine.

C. Heberle, Director der Grube Friedrichssegen bei Oberlahnstein.

Meinecke, Chemiker in Oberlahnstein.

Herzog, Betriebsingenieur der Krupp'schen Hüttenverwaltung in Sayn.

16. Lower Rhine.

Bergassessor von Velsen, Bonn.

Sachs, Director der Gesellschaft Humboldt in Kalk bei Cöln.

Ingenieur C. J. Langen, Cöln.

Hegener, Director der städtischen Gas und Wasserwerke in Cöln.

Frabrikbesitzer Dr. Grüneberg (Chemische Fabrik), Cöln.

Amendment to By-Laws.

Mr. F. Collingwood has proposed for the consideration of the Society the following amendment to the By-Laws, and on his motion, seconded by Mr. Wilson Crosby, it has been directed to be printed and issued with the announcement that it would be regularly moved at the approaching Tenth Annual Convention:

An Amendment to the By-Laws, to take the place of Section 31, adopted at the Ninth Annual Convention, April 25th, 1877.

Section .... Any member entitled to vote for officers of the Society may, before the third Wednesday of September in any year, nominate such officers for the ensuing year, by presenting the names of such nominees in writing, over his own signature, in a sealed envelope, addressed to the Board of Direction, and endorsed, "Nominations for officers."

The Board of Direction or those of its members present at a meeting of the Board, to be held on said third Wednesday of September, for this purpose, shall prepare a list in alphabetical order, under the title of each office, of all the persons thus nominated and eligible to the respective offices, together with the class of membership of each as to whether resident or non-resident.

Within one week thereafter, the Secretary shall mail such list, with a copy of this section, to all members of whatever class.

Members qualified to vote for officers may do so by striking from or adding to this list, and return the same as their ballots, but each ballot shall contain not more than one name for President, one for Secretary, one for Treasurer and one for Librarian, two names for Vice-President and five names for Directors. Of these, one Vice-President, the Secretary, the Treasurer, the Librarian and three Directors must be resident members.

The vote shall be by letter, in like manner as prescribed for admission to membersbip, and be canvassed at the Annual Meeting next succeeding said third Wednesday in September.

The presiding officer shall appoint three or more tellers for the canvass, who shall reject all ballots not in conformity with the Constitution and By-Laws, and report the result in full to the meeting in writing, such report to be preserved by the Secretary for reference.

The nominee for any office receiving the greatest number of legal ballots shall be declared elected to that office.

If, in any case, in consequence of two or more nominees receiving an equal number of votes, there is no election of a particular officer, the members present, who are entitled to vote, shall elect such officer by plurality ballot, from those nominees receiving the highest number of votes.

A ballot entirely in writing shall not be rejected for that reason.

Mr. Edward P. North has proposed for the consideration of the Society the following amendment to the Constitution, and on his motion, seconded by Mr. M. N. Forney, it has been directed to be printed and issued with the announcement that it would be offered at the approaching Tenth Annual Convention:

Amendment to Constitution.—To amend Article V, as far as relates to the election of a Secretary, as follows:

Hereafter the Secretary shall be appointed by the Board of Direction, and hold his office during their pleasure.

This amendment shall take effect on its passage, and its provisions shall apply to the Secretary elected in November next.

LIST OF NEW BOOKS ON

ENGINEERING AND TECHNOLOGY.

Alphabets; a Monogram and— Album. New York. New ed. 8vo. *Sabin.* $5.00.

Archæology. Lake Dwellings of Switzerland and other parts of Europe. F. Keller. New York. 2 vols. 8vo, illus. Plates. *Scribner, Wetford & Armstrong.* $21.00.

Architecture; Handy book of Villa ——. C. Wickes. London. 4to, illus. Plates. *Crosby, Lockwood & Co.* 42s.

———. Old homes made new, being a collection of Plans, exterior and interior views, illustrating the alteration and remodelling of several suburban residences, with explanatory text. W. Woollett. New York. Folio, illus. *Bicknell.* $1.50.

Art; Essay on Decorative. Geo. B. Warren, Jr. Troy. 8vo. *W. H. Young.* $0.25.

Atlantic, The: An Account of the General Results of the Voyage during the year 1873 and the early part of the year 1876. Sir C. Wyville Thomson, F. R. S. With a Portrait of the author, many colored Maps, Temperature Charts, and Illustrations. New York. 8vo. *Harpers.* $12.00.

Botany; Structural and Physiological ——. Otto W. Thorne, Professor of Botany at the School of Science and Art at Cologne. Trans. and ed. by A. W. Bennett, of St. Thomas' Hospital. 600 Woodcuts and colored Map. New York. Small 8vo. 2d ed. *Wiley & Sons.* $2.25.

Brakes; Continuous Railway ——. A Letter to the Right Hon. Sir Charles Adderley, President of the Board of Trade. By a frequent Railway Traveler. London. 8vo. *Trubner.* 6d.

Bridges; Practical Treatise on the Construction of Iron Highway ——. For the use of Town Committees: together with a short Essay upon the application of the principles of the Lever to a ready analysis of the strains upon the more customary forms of Beams and Trusses. With many fine Engravings. A. P. Boller, A. M., C. E. New York. 1 vol. 8vo, cloth. 2d ed. *Wiley & Sons.* $2.50.

Carriage Builders' Reference Book. With Illustrations and Descriptions of Centennial Exhibits. I. D. Ware. Philadelphia. 8vo, illus.

Catalogue; a general —— of choice books for the library; comprising a selection of the best books by ancient and modern authors, in all departments of literature, science, and art. Classified and priced. Cincinnati. 12mo. *Clarke.* $0.25.

Chairman's Handbook. 3d ed. Reginald F. D. Palgrave, Clerk-Assist. of the House of Commons. London. *Knight & Co.* 1s. 6d.

Chemistry, Industrial ——. A Manual for Technical Schools, Chemists and Manufacturers. Based upon a translation (partly by Dr. T. Barry) of Stohmann & Engler's German edition of Payens Precis de Chemie Industrielle. Edited throughout and augmented by B. H. Paul, Ph. D. Illustrated by 698 Engravings and containing nearly 1000 pages. New York. 8vo. *Wiley & Sons.* $10.00.

Corporations. The New York Act for the Formation of —— for Manufacturing, Mining, Mechanical, and other purposes. With all the Amendments. Notes, Forms, and Index. Compiled by a member of the New York Bar. New York. 12mo. *Baker, Voorhis & Co.* $0.50.

Design; a Primer of ——. Charles A. Barry, Supervisor of Drawing, Public Schools, Boston. *Lee & Shepard.* (Announcement.)

Drainage· House —— and water service in cities, villages, and rural neighborhoods. With incidental consideration of causes affecting the healthfulness of dwellings. Jas, C. Bayles. New York. 8vo. *D. Williams.* $3.00.

Drawing. An Elementary Course of Geometrical ——; containing Problems on the Right Line and Circle, Conic Section and other Curves, the Projection, Section, and Intersection of Solids, the Development of Surfaces, and Isometric Perspectives. With 38 Plates. 16 by 20. George L. Vose. Boston. *Lee & Shepard.* (Announcement.)

——— Elements of Machine Construction, or Machine Drawing, with some Elements of descriptive and rational cinematics. A text book for schools of Civil and Mechanical Engineering and for the use of Mechanical Establishments, Artisans and Inventors—containing the principles of Gearing, Screw Propellers, Valve Motions, and Governors, and many standard and novel examples, mostly from present American practice. S. Edward Warren, late Professor in the Rensselaer Polytechnic Institute. New York. 2 vols. 8vo, illus. plates. *Wiley & Sons.* $7.50.

——— Industrial—comprising the Description and uses of Drawing Instruments, the construction of Plane figures, the Projections and sections of Geometrical Solids, Architectural Elements, Mechanism and Topographical Drawing, for the use of academies and common schools. By Prof. D. H. Mahan. Revised and enlarged and chapter on colored topography added by Prof. D. F. Thompson of Troy. New York. 8vo, 30 plates. *Wiley & Sons.* $3.50.

Dynamics. Elements of——; Mechanics. With numerous Examples and Examination Questions. J. Blaikie. Edinburgh. Post 8vo. *Simpkin, London.* 3s. 6d.

Engineering. Aid book to —— enterprise abroad. Ewing Matheson. London. 8vo. *Spons.* 12s. 6d.

Engineers. Proceedings of the Association of Municipal and Sanitary —— and Surveyors. Edited by L. Angel. London. Vol. 3. 8vo. *Spons.* 10s. 6d.

Explosives. Guide book to the —— Act, 1875. For the use of local authorities and their officers. By Major Majendie, R. A., H. M. Inspector of Explosives. By authority. Bound in leather, 320 pages London. *Knight & Co.* 2s.

Graphical Statics. Elements of —— and their application to Framed Structures. With numerous practical Examples: Cranes, Bridge, Roof and Suspension Trusses; Braced and Stone Arches; Pivot and Draw Spans; Continuous Girders, etc; together with the best methods of calculation, and containing also new and practical formulæ for the Pivot or Draw -span, Braced Arch, Continuous Girder, &c. 2 volumes, 8 vo; 1 vol. text and 1 vol. plates—2d ed. Prof. A. Jay DuBois, Professor of Engineering in Sheffield Scientific School—late Professor at Lehigh University. New York. *Wiley & Sons.* $5.00.

Guide. The Pacific tourist, illustrated transcontinental —— of travel from the Atlantic to the Pacific Ocean. 1878. New York. 4to. *H. T. Williams.* $1.50.

Iron and Steel. The calculations of strength and dimensions of iron and steel constructions; with reference to the latest experiments. By Prof. J. J. Weyrauch, of Polytechnic Institute of Stuttgart. Translated by Prof. H. Jay DuBois. The only authorized translation. In 1 vol. New York. 8vo, plates. *Wiley & Sons.* $1.50.

Indian Population—How shall we treat the red man? Lieut. E. O. Otis, U. S. Army. New York. 12mo. *Sheldon.* $1.50.

Irrigation. Facts and Fallacies regarding —— as a Prevention of Famine in India. John Dacosta. London. 8vo. *W. H. Allen.* 6d.

Mechanics. Principles of Elementary —— designed to give more attention to the fundamental principles of mechanics. DeVolson Wood, Prof. of Mathematics and Mechanics in Stevens Institute. New York. 12mo, illus, cloth, 150 pp. Wiley & Sons. $2.00.

Military Enginee ing. Instructions in — —. Vol. I, part 4, Military Mining, compiled at the School of Military Engineering, Chatham. 2d ed. Post 8vo. British Government Publication. 1s. 6d.

Mineralogy, A Text-Book of ——, Based upon the System of Mineralogy by J. D. Dana. Embracing an extended treatise on Crystallography and Physical Mineralogy, By E. S. Dana, Curator of Mineralo y, Yale College. With upwards of 800 woodcuts, and one colored plate. New York. 8vo, cloth. 2d Ed. *Wiley & Sons.* $5.00.

———, A Manual of Determinative —— and Blow Pipe Analysis, by George Jarvis Brush, of Sheffield Scientific School. New York. 8vo. 2d Ed. *Wiley & Sons.* $3.00.

———, A new revision of the above, with New Notation, conforming with Dana's Text Book on Mineralogy. *Wiley & Sons.* (Announcement.)

Modern Countries, Resources of —— ——. Alex. J. Wilson. 2 vols. 8vo. *Scribner, Welford & Armstrong.* $12.00

Navy, Records of Living Officers of the United States —— and Marine Corps. Comp. from official sources. Lewis R. Hamersly. Philadelphia. 3d ed. rev. 8vo. *Lippincott.* $5.00.

———, The Gun, Ram, and Torpedo; or, Manœuvres and Tactics of a Naval Battle of the Present Day. By Com. Gerard Noel, R. N., the Royal Yacht. London. Crown, 8vo, illus. *Simpkin.* 8s. 6d.

Painting. Studio, Field and Gallery, A Manual of ——, for the Student and Amateur, with information for the general reader. Horace J. Rollin. New York. 12mo. *Appleton.* $1.50.

Pennsylvania Rail Road. History of the —— —— ——, Republished from the London Engineering. 220 pp. of text, 60 illustrations, more than 100 tables. 79 plates, including about 25 double page plates. 1 vol. folio, 450 pp. Half morocco. Sold by subscription. *Wiley & Sons.* Previous to issue, $15.00; after issue, $20.00.

Perspective, Second Grade —— (Theory and Practice). Specially prepared for the use of Art Students. H. J. Dennis. London. 4to. *Bailliere.* 2s. 6d.

Pocket Book of Useful Formulæ and Memoranda for Civil and Mechanical Engineers, with a valuable contribution on Telegraphs by R. S. Brough and Paget Higgs. G. L. Molesworth. London. 32mo. 19th Ed. *Spons.* 6s.

Railway Manual, Bradshaw's —— ——, Shareholder's Guide, and Official Directory for 1878. London. Post 8vo. *W. J. Adams.* 12s.

Sanitary Engineering. Wholesome Houses: Being an Exposition of the Banner System of Sanitation. 25th ed. Ed. G. Banner. London. 12mo. illus, *Crosby, Lockwood & Co.* 1s.

——— ———. Practical Information as to the Law relating to the Removal of Nuisances and Public Health. London. *Knight & Co.* 1s.

Science Lectures at South Kensington, Vol. I. By Capt. Abney, R.E., F.R.S.; Professor Stokes, Professor Alexander B. W. Kennedy, C.E.; F. J. Bramwell, Esq., C.E., F.R.S.; Professor F. Forbes, H. C. Sorby, F.R.S., J. T. Bottomley, M.A., F.R.S.; Sidney H. Vines, B.A., B.Sc.; Professor Carey Foster. New York. 12mo. *Macmillan.* $1.75.

Sea Terms, French —— —— and Phrases. By Lieut. Pornain, French Navy. London. 8vo. *Simpkin.* 4s.

Steam Engine. The Theory of the —— —— Trans. from the 4th ed. of Weisbach's Mechanics, by Prof. A. Jay DuBois. With an Appendix of Practical Examples of Stationary, Marine and Locomotive Engines, showing American practice, by R. H. Buel. New York. 8vo, illus. *Wiley & Sons.* $6.00.

—— —— Simple and Compound Engines. Their Relative Merits, by Niel Macdougall, Esq., Admiralty, London. Second Edit., demy 8vo, ills. 3s. 6d.

Statistical Tables. Hubner's Universal —— —— containing Area in square miles; Forms of Government; Head of ditto; Population; Expenditure; National Debt; Paper Money; Notes in Circulation; Standing Army; Navy; Merchant Vessels; Imports; Exports; Chief Native Produce; Money, Weights, and Measures; Chief Towns and Seaports; Population of Cities of all Countries in the World. 1 sheet imperial. London. *Trubner.* 1s. 9d.

Trades Unionism —— —— and its Results. Five Letters in the Times, with some additions, by Sir Edmund Beckett. London. Crown 8vo. *Crosby, Lockwood & Co.* 6d.

Tree Culturist. Fuller's Forest —— ———. The Cultivation of Forest Trees for Shade, for Shelter, for Fuel, for Timber, and for Profit. Illus. New York. *Am. News Co.* $1.00.

—— ——— Elliott's Lawn and Shade Trees. For Planting Parks, Gardens, Cemeteries, Private Grounds and Avenues. Fully illustrated and described. New York. *Am. News Co.* $1.00.

Tunnelling. Explosive Compounds and Rock Drills. Giving the details of Practical Tunnel Work. Properties of Modern Explo-

sives, Principles of Blasting, and Descriptions and Use of the various Rock Drills and Compressors, together with American and Foreign Systems of Arching, and Tables showing Cost and Dimensions of over 1700 Tunnels from every part of the world, and Profiles, Maps, and over 1000 illustrations, by Henry S. Drinker, Mining and Civil Engineer. New York. 4to. *Wiley & Sons.* Sold only by subscription. Price, previous to issue, $15.00 ; subsequent to issue, $20.00.

Ventilation A Treatise on —— Comprising lectures delivered before the Franklin Institute, showing the great want of improved methods of Ventilation in our buildings, giving the Chemical and Physiological process of Respiration, comparing the effects of the various methods of heating and lighting upon ventilation, etc. Illustrated by many plans of all classes of public and private buildings, showing their present defects, and the best means of improving them, by L. W. Leeds. New York. New ed. 1 vol. 8vo. illus. plates. *Wiley & Sons.* $2.50.

Vision. On defects of —— which are remediable by optical appliances. A course of lectures delivered at the Royal College of Surgeons of England. Robt. Brudenell Carter. London. 8vo. *Macmillan, New York.* $2.50.

Water Supply of Cities and Towns. A Comprehensive Treatise on the —— —— —— —— —— —— With numerous specifications of existing water works. William Humber. London. 1st American edition, 4to, illus., and 50 double plates. *Geo. H. Frost (Engineering News) Chicago.* Issued in 12 parts. For each part, $1.25 ; for 12 parts, $10.00.

ADDITIONS TO

LIBRARY AND MUSEUM.

From Administration dès Ponts et Chaussèes, Paris :

Annales dès Ponts et Chaussèes, March, 1878.

From Argentine Scientific Society, Buenos Ayres:

Annals of the Society, February and March, 1878.

From Austrian Society of Engineers and Architects, Vienna:

Transactions of the Society, Parts 3 and 4, 1878.

From Theodore Belpaire, Paris:

Tables permettant d'effectuer rapidement les calculs relatifs à la stabilité dès voûtes. Theodore Belpaire, Paris.

Essai d'une Théorie des Voutes en berceau, en arc de cercle et en plein centre. Theo. Belpaire, Paris.

From Boston Public Library:

The Bulletin of the Library, No. 45. April, 1878.

From the Buffalo Board of Water Commissioners:

Ninth Annual Report of the Buffalo City Water Works for 1877. Buffalo.

From the Engineers' Club of Philadelphia:

Report of the Committee of the Club on the Metric System of Weights and Measures. Philadelphia, 1878.

From the Hanover Society of Engineers and Architects:

Transactions of the Society, Part 2, 1878. Hanover, 1878.

From D. Farrand Henry, Detroit, Michigan:

The 26th Annual Report of the Board of Water Commissioners. Detroit. (3 copies.)

From A. L. Holley, New York:

The Strength of wrought iron as effected by its composition and by its reduction in rolling. Philadelphia, 1878. (10 copies.)

From the Imperial Russian Polytechnic Society:

Proceedings and Transactions of the Society. Vol. 1., 1878. St. Petersburgh.

From the Institution of Civil Engineers:

Minutes of Proceedings of the Society. Vol. LI. Session 1877-78, Part 1. London.

From John B. Jervis, Rome, N. Y.:

The Future of the Erie Canal. John B. Jervis. 1878.

From the Ministry of Public Works, Paris, France:

Year Book of Public Works for year 1878. Paris.

From E. P. North, New York:

Salisbury iron, its composition, qualities, and uses. Salisbury, Conn.

General Powder and Electric Blasting Apparatus. May, 1878. Lallin & Rand Powder Co., New York:

From the North of England Institute of Mechanical and Mining Engineers:

Transactions of the Society, November and December, 1877. Newcastle-upon-Tyne, 1878.

From Charles Paine, Cleveland, Ohio:

Eighth Annual Report of the President and Directors of the Lake Shore and Michigan Southern Railway. 1877. Cleveland, 1878.

From Ernest Pontzen, Paris, France:

Etude sur l'Exploitation des Chemins de fer par l'Etat. M. F. Jacquien, Paris.

Der Lupkower Tunnel der Ersten ungarisch galizischen Eizenbahn. Rudolph R. V. Gunesch, Vienna.

From Levi W. Post, Jersey City:

Annual Report of the Chief Engineer of the Board of Public Works of Jersey City. December 31, 1877. New York, 1878. (10 copies.)

From the Railroad and Warehouse Commission of Illinois:

Seventh Annual Report. Springfield, Ill.

From Hon. Saml. J. Randall:

Congressional Record, 45th Congress, 2d Session. April 21st, 1878, Washington.

From I. W. Smith, Sacramento, Cal.:

Report of the Board of Transportation Commissioners to the Legislature of California. December, 1877.

Explanation of Tables, &c., Supplementary Report of Board of Transportation Commissioners of California, January 14th, 1878.
Blanks for years 1876 and 1877 for reports of railroads to Board of Transportation Commissioners of California.
Legislative Acts in relation to Railroads of California. 1878.

From J. Herbert Shedd, Boston:
Report in relation to Sewerage of the City of Lynn, and a report of the Committee on Drainage. J. Herbert Shedd. Lynn. 1877.

From the Saxon Society of Engineers and Architects, Leipsic:
Transactions of the Society. 1877.

From the Technical and Administrative Military Committee, Vienna:
Communications upon Artillery and Engineering Operations. 2d part. 1878.

From the Treasury Department, Washington:
Annual Report of the Light House Board to the Secretary of the Treasury. 1877.

From R. H. Thurston, Hoboken, N. J.:
Thermal and Mechanical Properties of Air shown by lithographed curves due to changes of temperature, pressure and volume. R. H. Thurston. 1877.

Abstract of Statement of the extent and character of the work of the United States Board appointed to test Iron, Steel, and other Metals. R. H. Thurston. Salem, Mass.
On a new method of planning researches, and of representing to the eye the results of combination of three or more elements in varying proportions. R. H. Thurston. Salem, Mass.
The Growth of the Steam Engine. R. H. Thurston, New York, 1878.

From S Whipple, Albany, N. Y.:
An investigation as to the mode and amount of attraction between large and small bodies in contact or at small distances. S. Whipple. Albany, N. Y., 1877. (several copies.)

From H. M. Wightman, Boston:
Annual Report of the City Engineer of Boston for the year 1877.

From W. W. Wilson, Yonkers, N. Y.:
Fifth Annual Report of the Board of Water Commissioners of the City of Yonkers. 1877.

From David Williams, New York:
The Metallurgical Review. Vol. I.

From A. F. Wrotnowski, New Orleans, La.:
Report of the Board of State Engineers of Louisiana for the year 1876. New Orleans, 1878.

ANNOUNCEMENTS.

The Tenth Annual Convention of the Society will be held at Boston, beginning Tuesday, June 18th, 1878.

Sessions for the consideration of professional subjects, and one for the transaction of business will be held.

The meetings of the Convention will be held in the Hall of the Massachusetts Institute of Technology, on Boylston street, which has been kindly placed at the disposal of the Society for this purpose.

The first session of the Convention will be at 10 a. m., Tuesday, June 18th, and for that and the following days the following general programme is proposed:

Tuesday, June 18th.—Sessions at 10 a. m., and at 7½ p. m. During the afternoon, by invitation of the Boston Society of Civil Engineers, an excursion will be made by rail to Newton Upper Falls (Aqueduct Bridge, Boston Water Works), thence returning to the city *via* the Chestnut Hill Reservoir and suburbs of Boston.

Wednesday, June 19th.—Sessions at 10 a. m., and at 7½ p. m. Such portion of the evening session as may be determined upon to be for the transaction of business. During the afternoon several excursions to places of interest about the City of Boston will be made. Each of these excursions will be in charge of a member of the Local Committee, and visitors will elect which one to join.

Thursday, June 20th.—By invitation of the Boston Board of Trade, an examination of the upper harbor of Boston and its improvements, and an excursion down the harbor. Convention dinner in the evening, at the Hotel Brunswick.

Friday, June 21st.—By train to Lowell, and examination of the works of interest there. Thence to Lawrence, and, after visiting that City, return to Boston.

By invitation of Gen. A. P. Rockwell, President of the Eastern Railroad, an excursion will be made over that road to North Conway, and thence by the Portland & Ogdensburg Railroad to the Incline at Mount Washington.

The following is a list of topics to be considered with reference to papers published in Transactions during the preceeding year:

Bridges.

CXL. Approximate determination of stresses in the Eye-Bar Head. William H. Burr.

CXLIV and CXLIX. Relative quantities of material in bridges of different kinds, of various heights. Charles E. Emery.

CXLVII. Proportion of Eye-Bar Heads and Pins as determined by experiment. C. Shaler Smith.

CLVI. A new method of detecting overstrain in iron and other metals, and its application in the investigation of the causes of accidents to bridges and other constructions. Robert H. Thurston.

BOILERS.

CXLI. Connected-Arc Marine Boilers, a demonstration of the principles of their construction. CHARLES E. EMERY.

—— Discussion on above paper. J. FOSTER FLAGG. Vol. VI., page 294.

CEMENTS.

CLII. Notes and Experiments on the use and testing of Portland Cement. WILLIAM W. MACLAY.

DAMS.

CXLVIII. Wing Dams in the Mississippi above the Falls of St. Anthony. EDWARD P. NORTH.

HYDRAULICS.

CXXXIX. The Consumption and Waste of Water delivered by Public Works. JAMES H. HARLOW.

CXLV. The flow of water in open channels. THEODORE G. ELLIS.

CLIV. A peculiar case of failure in a water main. D. MCN. STAUFFER.

— Discussion on above paper. Vol. VII, p. 15.

MASONRY.

CLI. Nomenclature of Building stones and stone Masonry. J. JAMES R. CROES, WILLIAM E. MERRILL and EDGAR B. VAN WINKLE.

MINES AND BLASTING.

CXLII. On the simultaneous ignition of thousands of mines and the most advantageous grouping of fuses. JULIUS H. STRIEDINGER.

CLIII. On igniting blasts by means of electricity. JULIUS H. STRIEDINGER.

PRESERVATION OF TIMBER.

—— Discussion on this subject. Vol. VI, page 189.

RAILROADS.

CLVIII. Construction and operation of the Incline Plane Railroad at Madison, Ind. M. J. BECKER.

RIVERS AND HARBORS.

CXLIII. Improvement of Entrance to Galveston Harbor. CHARLES W. HOWELL.

CLV. The Improvement of the South Boston Flats. EDWARD S. PHILBRICK.

—— Discussion on Levees as a system for reclaiming low lands. J. FOSTER FLAGG. Vol. VI, page 305.

STEAM ENGINES.

CLVII. Steam engine economy. A uniform basis for comparison. CHARLES E. EMERY.

SURVEYS.

CXXXVIII. Co-ordinate Surveying. HENRY F. WALLING.

CXLVI. A novel railroad survey. THOMAS S. HARDEE.

CL. Description of survey for determining the slope of water surface in the Erie Canal. WILLIAM H. SEARLES.

In addition to the above papers, it is expected that the following subjects will be presented by papers printed previous to the date of the Convention, or read at its meeting :

Dams across Water Courses. WILLIAM J. MCALPINE.

The rain fall during a storm in October, 1869. JAMES B. FRANCIS.

The law of Tidal Currents. J. H. STRIEDINGER.

The South Pass Jetties ; descriptive and incidental notes and memoranda. E. L. CORTHELL.

Discussion on the preceding paper. CHARLES W. HOWELL.

Reminiscences and experiences of early engineering operations on railroads, with especial reference to steep inclines.

No. 1, W. MILNOR ROBERTS.

No. 2, WILLIAM J. MCALPINE.

Resistances on Railway Curves. S. WHINERY.

Notes on the papers in reference to Incline Planes and Resistances on Railway Curves. —OCTAVE CHANUTE.

Agricultural Drainage. ED. N. KIRK TALCOTT.

A graphic method of representing railroad accounts. CHARLES LATIMER.

Science, old and new. Its relation to Engineering. W. MILNOR ROBERTS.

The Mississippi River.—B. M. HARROD.

Brick Arches for Large Sewers. R. HERING.

Improvement of Galveston Harbor (2d Paper). CHARLES W. HOWELL.

The Flow of Water in Pipes. CHARLES G. DARRACH.

The proper arrangement and ventilation of house drains. CHARLES E. FOWLER.

On a newly discovered relation between the tenacity of metals and their resistance to torsion. R. H. THURSTON.

On Gauging Streams. CLEMENS HERSCHEL.

Members of the Society are earnestly requested to furnish information or memoranda upon any of the subjects referred to. They are also invited and expected to take part in the discussions either in person or by sending to the Secretary notes for presentation.

In either case, it will assist the Committee in arranging the details for sessions of the Convention, if Members expecting to take part in the discussions will notify the Secretary at once to that effect.

Reports will be expected, as follows :

From Committees on Gauging of Streams, J. James R. Croes, Chairman ; Permanent Quarters for the Society, John Bogart, Chairman ; Resistances of Railway Trains, William P. Shinn, Chairman : Uniform Accounts and Returns of Railroad Companies, William P.

Shinn, Chairman; Tests of American Iron and Steel, W. Sooy Smith, Chairman; On Exhibit at the Paris Exposition, Geo. S. Morison, Chairman; The Centennial Commission of the Society, Theodore G. Ellis, Chairman.

Members who intend to be present at the Convention are requested to immediately notify the Secretary to that effect, either upon the blanks already sent out or otherwise.

Transportation for Members has been already secured over many lines, and it is hoped will be obtained over others. Notice of what can be furnished will be sent to Members expecting to visit the Convention.

The Boston Society of Civil Engineers; the Engineers' Club of the Northwest, of Chicago; the Engineers' Club of St. Louis; the Engineers' Club of Philadelphia, and the New Haven Engineering Society, have been invited to attend the Convention. The Local Committee has made arrangements for Members at reduced rates ($3.50 per day) at the Hotel Brunswick, on Boylston street, which is opposite the place of meeting of the Convention.

Invitation to visit the works of interest at and in the vicinity of Fall river is extended to all visitors to the Convention, by Mr. Wm. Rotch, Chief Engineer of the Fall River Water Works, and Member of the Society. Among these works are an iron bridge for railroad and highway over the Taunton river; the water works of the City, and some of the forty cotton mills, which, together, contain 1 250 000 spindles. These works can be visited either before or after the Convention.

Arrangements have been made for the trip from New York to Boston and return, by Sound steamers, at $3.00 the round trip, not including stateroom. Most of the members purpose leaving New York on Monday evening, June 17th.

Notify the Secretary at once if you desire a berth reserved for you in stateroom.

Discordant Standards of Measurement.—A number of members of the Society desire to obtain for publication, statements of the various discordant standards of measure in use in the United States. It is known that in many cities the old standards are more or less at variance with the present, and that, quite frequently, confusion and annoyance are the result. A table, compiled from the information which is undoubtedly in the possession of members of the Society, would be both interesting and valuable. The request is, therefore, made, that any information which would be of assistance in the preparation of such a table be forwarded to the Secretary. The replies should state the equivalent of the measures referred to in U. S. standard feet or in meters, together with any additional notes which may be applicable. If provisional equivalents, afterwards proving incorrect, have been adopted, the value of these should also be stated.

In the Transactions of the Society of Engineers and Architects of Hanover, Vol. XXIV., No. 2, 1878, there is an abstract of the Paper by John T. Fanning, member of this Society, entitled "A Water Conduit under Pressure," which was published as Paper No. CXXXVI., Transactions, Vol. VI., page 69, March, 1877.

Members of the Society who expect to visit Europe during the present year, are requested to inform the Secretary as soon as possible of that fact, and also of the time when they purpose leaving and the probable length of their stay abroad, together with their European address.

Members who desire to secure complete sets of the Transactions of the Society are requested to send to the Secretary a list of the papers which are needed to fill up their sets. Some of the earlier papers are out of print. If orders are received for a sufficient number to warrant the expense, a reprint will be made.

The following resolution was adopted at the Ninth Annual Convention of the Society and ordered printed regularly in the Society publications:

Whereas, the metric system of weights and measures is now extensively used abroad; and whereas, it is desirable that the relation of the units of differing systems be made familiar to all, by comparison:

Resolved, That Members be requested, in papers hereafter presented to the Society to write, in parenthesis, weights or dimensions by the metric system in connection with those of the system in general use.

The House of the Society is at 104 East Twentieth street, one door east from Fourth avenue, and near southwest corner of Gramercy Park. It is open from nine o'clock A. M. to five o'clock P. M. each business day except Saturday, when it is closed at three o'clock P. M.

The Library and Conversation Rooms will also, for the present, be open every *Thursday evening*, from 7½ to 10 P. M. Members are invited to avail themselves of the opportunities afforded on Thursday evenings both for consultation of books and periodicals and for conversation.

LIST OF MEMBERS.

ADDITIONS.

MEMBERS.

		Date of Election.
FORCE, C. G., JR	City Civil Engineer's Office, Cleveland, Ohio	Feb. 6, 1878.
GREENE, B. H	Chief Engineer, New Orleans Pacific Ry., New Orleans, La	May 1, 1878.

CHANGES AND CORRECTIONS.

MEMBERS.

DICKINSON, P. P. ..... 35 Coal and Iron Exchange, New York.

EVANS, WALTON W. ..... 66½ Pine Street, New York.

GREENE, DAVID M. ..... Troy, N. Y.

LANE, MOSES ..... 1616 Grand Ave., Milwaukee, Wis.

OWEN, JAMES ..... Civil Engineer, 748 Broad Street, Newark, N. J.

JUNIORS.

MACY, ARTHUR ..... 26 Cedar Street, New York.

RAYMOND, CHARLES W. ..... Dept. of Docks, foot of Barrow Street, New York.

ASSOCIATE.

HARRIS, CHARLES M. ..... (Care Am. Soc. Civil Engs.), New York.

FELLOW.

FLINT, CHARLES R. ..... 87 Wall Street, New York.

RESIGNED.

MILLER, J. IMBRIE ..... Member ..... May 7, 1878.

American Society of Civil Engineers.

PROCEEDINGS.

Vol. IV, April, 1878.

MINUTES OF MEETINGS.

(Abstract of such as may be of general interest to members.)

OF THE SOCIETY.

May 1st, 1878.—The Society met at 8 p. m. Past President William J. McAlpine in the chair.

The Committee on the Exhibit at Paris, reported progress.

A paper entitled "Reminiscences and experiences of early engineering operations on railroads, with especial reference to steep inclines," by W. Milnor Roberts, was read by the Secretary. This paper and the one read at last meeting upon the "Incline at Madison, Indiana," were discussed by Messrs. Bogart, Chanute, Emery, Forney, W. J. McAlpine, North and W. H. Paine.

The ballot upon admission to membership was canvassed, and the following were declared elected as Members of the Society: Benjamin H. Greene, of New Orleans, La.; Samuel L. James, of New Orleans, La.; and George B. Nicholson, of Cincinnati, O.

May 15th, 1878.—The Society met at 8 p. m., Vice-President Roberts in the chair.

A paper entitled "On the Theoretical Resistances of Railroad Curves," by Samuel Whinery, was read by the Secretary, and the subject discussed by Messrs. Crosby, Emery, C. L. McAlpine, North, W. H. Paine, Searles and Yardley. The discussion being unfinished, was adjourned till the next meeting.

June 5th, 1878.—The Society met at 8 p. m., Vice-President Roberts in the chair.

Ballots for admission to Membership were canvassed, and the following were declared elected :—

As Members, William J. Nicolls, of New York, and Thomas Rodd, of Pittsburgh, Pa.

As Associate, Edward R. Andrews, of Boston, Mass.

The Secretary reported arrangements in progress for the Tenth Annual Convention.

Drawings and descriptions of a bridge erected in Holland over the Hollandsch Diep, presented by Mr. Walton W. Evans, were laid before the Society.

The proposed amendment to the Constitution, printed at page 28, Proceedings, Vol. IV. *ante*, was offered for the consideration of the Society, by Edward P. North, and seconded by M. N. Forney, and on motion, it was ordered printed and sent out before the meeting of Convention.

The proposed amendment to the By-Laws, printed at page 28, Proceedings Vol. IV., *ante*, was presented by F. Collingwood, on whose motion, seconded by Wilson Crosby, it was ordered printed, and sent out, with the announcement that it would be moved at the Convention.

The discussion on the subject of Resistances on Railway Curves was then resumed, and continued by Messrs. Chanute, Collingwood, Emery, A. Fink, Forney, North, W. H. Paine, Searles and Worthen.

June 19th, 1878.—Business meeting at the 10th Annual Convention in Boston. The Society met at 8½ p. m., in business session, Vice-President Roberts in the chair.

The proposed amendment to the Constitution, printed at page 28, Proceedings, Vol. IV., *ante*, was discussed by Messrs. North, J. D. Steele, Bogart, George S. Greene, Herschel, Philbrick, Holley, Flagg, Croes, Joseph P. Davis, Latimer, Collingwood and Emery.

This amendment, under the rule, will be again presented at the next annual meeting.

The proposed amendment to the By-Laws, printed at page 28, Proceedings, Vol. IV., *ante*, was then presented, and discussed by Messrs. Collingwood, Croes, George S. Greene, Bogart, Morison, Philbrick, Brooks and Holley.

The amendment was then withdrawn, and the following resolution, offered by J. J. R. Croes, and seconded by F. Collingwood, was passed:

Resolved, That a committee of three be appointed by the presiding officer to examine into the methods of election of officers adopted by various clubs and societies, and report to the Society a By-Law embodying such features of the various plans as may seem best adapted for this Society.

Under this resolution the following committee was appointed:

J. J. R. Croes, E. S. Philbrick and F. Collingwood.

The business meeting of the Society then adjourned, and the session of the Convention was resumed.

Tenth Annual Convention of the Society.

First Session.—The Tenth Annual Convention was held at Boston beginning Tuesday, June 18th, 1878. The Society met at the Hall of the Massachusetts Institute of Technology, Boylston street, which had been kindly offered for its use. The secretary, John Bogart, called the Convention to order at 10 A. M., and stated that the President, E. S. Chesbrough had fully expected to be present but that a pressure of public duties in Chicago made his absence from that city impossible at this time, to his great regret. Under these circumstances it would devolve upon the Senior Vice-President, W. Milnor Roberts, to open the Convention, after a record of the members present had been obtained.

The roll was then called and the following members and guests were found in attendance :

Members of the Society—S. T. Abert, Washington, D. C.; C. F. Allen, E. R. Andrews, F. W. Bacon, F. Brooks, E. W. Bowditch, Boston ; W. S. Barbour, Cambridgeport ; A. D. Briggs, Springfield ; H. Bissell, Salem, Mass.; J. W. Bacon, Danbury, Conn.; W. D. Bullock, Pawtucket, R. I.; John Bogart, New York ; P. Barnes, Plainfield, N. J.; C. E. Billin, G. Burnham, Jr., Philadelphia ; A. Bonzano, Phœnixville, Pa.; D. W. Cunningham, Boston ; I. E. Clark, Cambridge, J. G. Chase, Cambridgeport ; O. E. Cushing, Lowell ; W. R. Curtis, Rockland, Mass.; J. P. Cotton, Newport, R. I.; F. Collingwood, J. J. R. Croes, New York ; M. Coryell, Lambertville, N. J.; T. C. Clarke, Philadelphia ; F. W. Clarke, Chicago ; W. B. Cogswell, Mine La Motte, Mo.; E. L. Corthell, New Orleans ; J. P. Davis, Boston ; C. G. Darrach, Philadelphia ; E. A. Doane, Meadeville, Pa.; S. C. Ellis, Boston ; J. E. Early, College Hill ; C. D. Elliott, Somerville, Mass.; T. G. Ellis, Hartford ; M. T. Endicott, New London, Conn.; C. E. Emery, New York ; R. Fletcher, Hanover ; J. T. Fanning, Manchester, N. H.; E. A. Flint, A. Fteley, Boston ; J. B. Francis, Lowell, Mass.; C. Fisher, Trenton, N. J.; J. F. Flagg, Meadville, Pa.; R. Fink, Alexandria, Va.; C. G. Force, Cleveland, O.; S. M. Gray, Providence, R. I.; J. P. Gould, Rondout, N. Y.; G. S. Greene, G. S. Greene, Jr., New York ; G. C. Gardner, Altoona, Pa.; P. Golay, Cincinnati, O.; W. A. Haven, Brattleboro, Vt.; A. S. Hardy, Hanover, N. H.; C. Herschel, Boston ; J. H. Harlow, Lowell, Mass.; A. B. Hill, New Haven, Conn.; W. G. Hamilton, A. L. Holley, New York ; R. Hering, Philadelphia ; J. W. Hill, Hamilton, O.; M. Hjortsberg, Chicago ; T. S. Hardee, New Orleans ; G. A. Kimball, Somerville, Mass.; G. O. Knapp, Hartford, Conn.; W. E. Kelley, New Brunswick, N. J.; L. H. Knapp, Buffalo, N. Y.; John Kennedy, Montreal ; J. C. Kennedy, Ontario, Canada ; C. Latimer, Cleveland, O.; W. H. Lotz, Chicago ; M. Lane, Milwaukee ; G. P. Low, Jr., Boston ; E. D. Leavitt, Jr., Cambridgeport, Mass.; D. J. Lucas, Warren, Pa.; T. D. Lovett, Winton Place, Ohio ; A. Macy, Geo. S. Morison, New York ;

C. C. Martin, Brooklyn; D. N. Melvin, Staten Island, N. Y.; H. G. Morris, Philadelphia; D. E. McComb, Washington; B. F. Morse, Cleveland, O.; G. H. Norman, Boston; E. P. North, New York; J. O. Osgood, Milton, Mass.; L. F. Olney, Buffalo, N. Y.; E. S. Philbrick, Boston; L. W. Post, Jersey City; P. A. Peterson, Montreal; W. Rotch, Fall River, Mass.; W. Milnor Roberts, New York; R. L. Read, Cincinnati, O.; W. H. Searles, New York; A. Spielman, Hoboken, N. J.; D. McN. Stauffer, Philadelphia; J. D. Steele, Pottstown; W. P. Shinn, Pittsburgh, Pa.; E. T. Scovill, Cleveland, O.; R. H. Thurston, Hoboken, N. J.; E. N. K. Talcott, Morgan Park, Ill.; J. Veazie, H. W. Wightman, H. F. Walling. W. H. White, F. O. Whitney, Boston; J. Whitney. Cambridge; N. H. Whitten, Holyoke, Mass.; F. W. Whitlock, W. H. Wiley, New York; De V. Wood, Hoboken, N. J.; Geo. Y. Wisner, Detroit; T. J. Whitman, St. Louis.

Visiting Engineers.—E. Appleton, T. Appleton, C. D. Austin, D. Brackett, F. H. Barrett, W. H. Bradley, G. W. Blodgett, J. E. Cheney, J. R. Carr, Jr., Jos. H. Curtis, Geo. H. Crafts, E. C. Clarke, F. L. Fuller, F. D. Fisher, D. Fitzgerald, O. Hodges, E. W. Howe, C. W. Kettell, W. H. Lemon, W. F. Learned. C. W. Lunt, F. A. May, J. D. Mason, H. Manley, G. S. Rice, L. F. Rice, R. H. Richards, W. Shepard, F. C. Tucker, I. S. P. Weeks, C. Whitaker, Boston; C. W. Folsom, Cambridge; Geo. R. Hardy, Springfield;* C. Pfeifer, F. H. Pond, Chas. A. Smith, St. Louis;† T. C. Bradley, Geo. H. Frost, A. Wolcott, Chicago;‡ C. A. Ashburner, W. Burnham, G. R. Buckman, C. Constable, W. A. Cooper, G. H. Christian, J. B. Knight, H. C. Lewis. T. J. Lewis. W. Lewis, A. E. Lehman, T. C. McCollom, L. C. Madeira, J. T. Morris, P. Roberts, Jr., C. Sellers, Jr., H. Sellers, F. W. Taylor, Philadelphia;§ J. P. Henck, A. G. Hills, A. P. Rockwell, Boston; A. W. Hunking, Lowell; D. H. Johnson, Salem, Mass.; C. A. Ferry, New Haven, Conn.; W. H. McFadden, W. M. McFadden, Philadelphia; R. H. Soule, Altoona, Pa.; J. P. Rockwell, Denison, Texas.

Vice-President Roberts then made an introductory address,‖ and announced that in accordance with the rules, a presiding officer would be chosen by the Convention.

Edward S. Philbrick, of Boston, was chosen to preside at the Convention, and John Bogart to act as Secretary.

In taking the chair, Mr. Philbrick said:

I thank you for the unexpected honor which you have conferred upon me this morning; and before calling your attention to the business in hand, I can only say, that when the circular was first sent to me by your secretary, asking me to vote where the Convention should meet, I did not vote for Boston, because I felt a degree of diffidence—that we might

* Members Boston Society Civil Engineers. † Members Engineers' Club of St. Louis ‡ Members Engineers' Club of the North West. § Members Engineers' Club of Philadelphia. ‖ This address will be hereafter published.

not be able to present to the Society those objects of interest which have been presented to us in other cities. But, as the Society has done us the honor to come here, I can certainly extend to you the hand of fellowship, which is about all we can do, and give you a most hearty welcome to the old City of Massachusetts. There is not much that we can do in the way of professional entertainment. We hope to spend a few afternoons in seeing some of the objects most worthy of interest in the neighborhood of Boston and the cities of Lowell and Lawrence, which are among the great manufacturing centres of New England, and which have been rather typical cities in that respect, being prominent in introducing the cotton manufacture into the United States, and building it up; and there also, perhaps, you will find subjects a little more akin to our profession in the apparatus which has been devised for gauging the flow of water, a subject which, of course, interests a large part of our profession who have devoted themselves to that specialty.

But our time is limited, gentlemen, and I will now call your attention to the business for which we are here assembled. As we are, I hope, a law-abiding body, I would call upon the Secretary to read the general rules by which our conventions are governed.

The rules were then read.*

The subject of Bridges was announced.

The following papers were considered :

CXL. Approximate determination of stresses in the Eye-Bar Head. William H. Burr.

CXLVII. Proportion of Eye-Bar Heads and Pins as determined by experiment. C. Shaler Smith.

The subject was discussed by De Volson Wood.†

The following paper was considered :

CLVI. A new method of detecting overstrain in iron and other metals, and its application in the investigation of the causes of accidents to bridges and other constructions. Robert H. Thurston.

A paper,† by R. H. Thurston, entitled "On a newly discovered relation between the tenacity of metals and their resistance to torsion," was then read by the Secretary.

A description of the recent accident to a strand of the Brooklyn Bridge† was then given by Francis Collingwood, and discussed by Messrs. Wood, Croes and Emery.

The following papers were considered :

CXLIV and CXLIX. Relative quantities of material in bridges of different kinds, of various heights. Charles E. Emery.

The subject was discussed† by Messrs. Searles and Emery.

The subject of Rivers and Harbors was then taken up. A paper, by E. L. Corthell, entitled "The South Pass Jetties, descriptive and incidental notes and memoranda,"† was read by the author.

* The rule limiting the time of reading for each paper and of each member taking part in the discussions to ten minutes, except by unanimous consent, was enforced during the whole session of the Convention.

† To be hereafter published.

A discussion of this paper by C. W. Howell* was read by the Secretary.

The subject was also discussed by W. Milnor Roberts.*

A communication was read from the President of the Massachusetts Institute of Technology, inviting the members of the Society to inspect the several departments of the institute, which was accepted. A communication from the Boston Board of Trade, inviting the members of the Society to avail themselves of the facilities of the Merchants' Exchange and Reading Room, was read and accepted. Announcements were made of arrangements for the afternoon excursions. The Convention adjourned to 7½ P. M.

SECOND SESSION.—The Convention resumed its session at 7½ P. M.

The consideration of the subject of rivers and harbors was continued and discussed by J. Foster Flagg.*

A paper,* by B. M. Harrod, entitled "The dangers threatening the navigation of the Mississippi River and the reclamation of its alluvial lands," was read by the Secretary.

The subject was discussed* by Messrs. T. S. Hardee, E. L. Corthell, W. Milnor Roberts, John Kennedy, and J. Foster Flagg.

The following papers were then considered:

CXLIII. Improvement of entrance to Galveston harbor. Charles W. Howell.

CLV. The Improvement of the South Boston Flats. Edward S. Philbrick.

——— Discussion on Levees as a system for reclaiming low lands. J. Foster Flagg. Vol. VI., page 305.

Some explanations as to the improvements in Boston harbor were given by E. S. Philbrick, and it was stated that as one of the excursions of the Society was to be down the harbor and past these improvements, full information on the subject would be given on that occasion.

In answer to a question E. P. North gave a description of the means adopted for checking the moving back of the Falls of St. Anthony.*

The Committee on Ganging of Streams then made a report.*

The subject of Ganging Streams was discussed by Clemens Herschel.

The following paper was then considered:

CXLV. The flow of water in open channels. Theodore G. Ellis.

Remarks* upon the subject were made by Messrs. J. B. Francis, T. G. Ellis, W. M. Roberts, C. E. Emery, C. Hershel, and De Volson Wood, and it was discussed by Messrs. White, J. P. Davis, Latimer and Walling.

A paper, by Charles G. Darraeh, entitled "The Flow of Water in Pipes,"* was read by the author.

Remarks upon the subject* were made by John T. Fanning.

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* To be hereafter published.

A letter was read from S. N. Gray, member of the Society, City Engineer of Providence, inviting the members of the Society to visit that City on their return from Boston, which invitation was accepted.

The Convention then adjourned to Wednesday, June 19th, at 10 A. M.

THIRD SESSION.—The Convention reassembled at 10 A. M., on Wednesday, June 19th. Announcements were made of details of excursions for the afternoon.

The subject of cements was announced.

The following paper was considered :

CLII. "Notes and experiments on the use and testing of Portland Cement. William W. Maclay.

A discussion* on the subject by Don J. Whittemore was read by the Secretary.

The subject was also discussed by Francis Collingwood.*

J. Dutton Steele offered the following resolution :

Resolved, That the members present have listened with much interest to the paper read by E. L. Corthell upon the jetty improvements at the mouth of the Mississippi ; and that while we may differ individually as to the precise effects they are to produce, we are in hearty sympathy with the undertaking, and fully appreciate the importance in a national and commercial point of view of thus improving the outlets of our great rivers.

This resolution was discussed by Messrs. J. D. Steele, T. G. Ellis, Roberts, Latimer, and Herschel.

On motion this resolution was laid on the table.

C. Herschell offered the following resolution :

Resolved, That this Society of Civil Engineers, in convention assembled, is heartily glad to hear that there is a twenty-four feet channel at the mouth of the Mississippi river to-day, and that they hope that Capt. Eads will secure thirty feet.

This resolution was discussed by Messrs. J. B. Francis, Latimer, North, J. D. Steele, D. V. Wood, and Collingwood.

C. Latimer moved that a committee of three be appointed to frame a resolution on the subject.

On motion of J. B. Francis, the whole subject was indefinitely postponed.

The subject of masonry was announced.

A paper* by R. Hering, entitled "Brick arches for large sewers," was read by the author.

W. Milnor Roberts made remarks* upon the subject, and it was discussed by Messrs. Collingwood, Hering and Morison.

A communication* on the same subject from E. S. Chesbrough was read by the Secretary.

The topic of cements was resumed, and remarks* upon the subject were made by W. P. Shinn.

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* To be hereafter published.

The topic of masonry was resumed, and the following paper considered :

CLI. Nomenclature of Building stones and stone Masonry. J. James R. Croes, William E. Merrill, and Edgar B. Van Winkle.

Remarks upon the subject* were made by J. Foster Flagg, and it was discussed by Messrs. Croes, Collingwood and Veazie.

The topic of hydraulics was resumed.

A paper* by James B. Francis, entitled "The rain fall during a storm in October, 1869," was read by the author.

The topic of dams was announced.

The following paper was considered:

CLVIII. Wing Dams in the Mississippi above the Falls of St. Anthony. Edward P. North.

Remarks* upon the subject were made by T. G. Ellis and E. P. North.

The convention then proceeded to the business prescribed by the following clause of the By-Laws† which was read.

"At the Annual Convention a Nominating Committee of five members, not officers of the Society, shall be appointed by the Convention."

The following resolution was offered by George S. Greene, and lost :

Resolved, That a Committee of three be appointed by the chair to hand in the names of five persons to be proposed to the Convention for the nominating committee, under the By-Laws, and that the names of the five persons shall be from the geographical divisions of the country."

The method of nominating the Committee was discussed by Messrs. George S. Greene, Gardner, Emery, T. G. Ellis, Bogart, Searles, De Volson Wood, Croes and others.

The following resolution offered by De Volson Wood was adopted :

Resolved, That the Convention nominate the committee, and as far as possible it be geographically divided.

The convention then adjourned to 7½ P. M.

Fourth Session.—The Convention reassembled at 7½ P. M.

The following resolution, offered by G. C. Gardner, was adopted :

Resolved, That the members of the Nominating Committee be selected from the following districts of the country : New York and the Atlantic coast, Pittsburgh and the Ohio valley, Chicago and the Lake region, St. Louis and the Mississippi valley, New Orleans and the South.

Nominations were then made, and the following named members were appointed by the Convention as the Nominating Committee :

George S. Morison, of New York.
William P. Shinn, of Pittsburgh.
M. Hjortsberg, of Chicago.
James B. Eads, of St. Louis.
Thomas S. Hardee, of New Orleans.

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* To be hereafter published. † Proceedings, Vol. III, p. 26.

The Committee on Resistances of Railway Trains reported,* through its chairman, W. P. Shinn.

On motion, the committee was continued.

A paper*, by Richard H. Buel, on the subject of the Dynograph, was then presented.

The Committee on Uniform Accounts and Returns of Railroad Companies reported,* through its chairman, W. P. Shinn.

On motion, the committee was continued.

A paper,* by Charles Latimer, upon the subject of the Graphic Representation of Railroad Accounts, was then read by the author, and illustrated by a large chart.

The report of the Committee on Permanent Quarters for the Society,* was presented by F. Collingwood, member of the committee.

On motion, the committee was continued.

The report of the Committee on Tests of American Iron and Steel,* forwarded by its chairman, W. Sooy Smith, was read.

On motion, the committee was continued.

The report of the Committee on the Exhibition of American Engineering at the Paris Exposition of 1878,† was presented by its chairman, George S. Morison.

A statement of the work done by the committee, the exhibits secured, and the expenses and receipts to the present time was made, on behalf of the committee, by George S. Morison, chairman, and illustrated by a model of the structure erected for the purpose of securing the largest amount of wall surface on the floor area allotted to the Society, together with sufficient space for the exhibit of models, portfolios, etc.

Remarks were then made by T. C. Clarke, who had just returned from Paris, in reference to the interest felt abroad in American Engineering, which was first developed by the Exposition at Philadelphia, and which it was hoped would be strengthened by this exhibit.

The subject was discussed by Messrs. J. D. Steele, Latimer, Bogart, Herschel, and others.

On motion of J. Dutton Steele, it was ordered that the Committee on the Exhibit at Paris be requested to prepare a subscription paper to be presented to the members present at the Convention, and also sent by mail to all members of the Society.

The Centennial Commission of the Society presented a report,* through its chairman, T. G. Ellis,

On motion the Commission was continued.

The question of the time and place for the next Annual Convention was then considered.

An invitation to hold the Convention at St. Louis was extended to the Society, through T. J. Whitman, of St. Louis.

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* To be hereafter published. † This report has been printed and sent to members.

The Convention adjourned till the close of the business session of the Society, which was then held.

FIFTH SESSION.—At the close of the business meeting of the Society, the Convention resumed session.

The topic Steam Engines was called up. The following paper was considered :

CLVII. Steam engine economy: A uniform basis for comparison. Charles E. Emery.

The subject was discussed by Messrs. Leavitt, Flagg, Emery and Whitaker.

Under the topic Hydraulics, the following paper was considered :

CXXXIX. The Consumption and Waste of Water delivered by Public Works. James H. Harlow.

The topic Mines and Blasting was called up, and the following papers referred to :

CXLII. On the simultaneous ignition of thousands of mines and the most advantageous grouping of fuses. Julius H. Striedinger.

CLII. On igniting blasts by means of electricity. Julius H. Striedinger.

The author of these papers being absent in Europe, their discussion was postponed.

The subject of Preservation of Timber was referred to as having been exemplified on one of the excursions made to the works in South Boston.

The topic of Railroads was announced, and the following papers considered :

CLVIII. Construction and operation of the Incline Plane Railroad at Madison., Ind. M. J. Becker.

CLIX. Resistances on Railway Curves. S. Whinery.

——— Notes on the papers in reference to Incline Planes and Resistances on Railway Curves. Octave Chanute.

——— Reminiscences and experiences of early engineering operations on railroads, with especial reference to steep inclines. W. Milnor Roberts.

Notes* on the question of elevation of the outer rail on curves by E. Yardley were read by the Secretary, and discussed by Messrs. J. D. Steele, Philbrick, Roberts and Latimer.

The subject of Surveys was announced.

The following papers were considered :

CXXXVIII. Co-ordinate Surveying. Henry F. Walling.

CXLVI. A novel railroad survey. Thomas S. Hardee.

CL. Description of survey for determining the slope of water surface in the Erie Canal. William H. Searles.

The latter paper was discussed by Messrs. Roberts and Croes.

After announcing the arrangements for excursions during the succeeding days of the week, that for the following day being down the Harbor of Boston and as far as Minot's Ledge Light House, E. S. Philbrick, by request, gave a description of the old light house at that point and its destruction.

* To be hereafter published.

The following resolutions were passed ;

"Resolved, that this Convention desires to express its hearty appreciation of, and thanks for, the great kindness and many favors extended to the members and guests of the Society by the Boston Society of Civil Engineers during the session of the Convention."

"Resolved, that the thanks of the Society be conveyed to the members of the local committees for the very thorough manner in which their duties have been performed, and to the Boston Board of Trade, the officers of the Massachusetts Institute of Technology and to the officers of the railroads which have courteously afforded to the members of the Convention facilities for transportation and for examining the works of interest in the vicinity of Boston."

"Resolved, that the thanks of this Convention be extended to Mr. Edward S. Philbrick for the able and courteous manner in which he has presided over its deliberations."

The Convention then adjourned.

The section of the By-Laws providing for conventions reads as follows : "A convention of the Society for professional discussion and social intercourse shall be held annually, at such place as the Society may determine," * * * &c.

In addition to the sessions for professional discussions, as above reported, provision was made by the local committees at Boston for excursions and visits to many points of interest. Nearly all the members of the Society and their guests who attended the convention took part in these excursions, which, through the excellent arrangements characterizing them, added largely to the pleasure of the occasion, both in the interesting engineering works visited and in the opportunities afforded for social intercourse. Members of the families of many of the engineers also accompanied them in these excursions, and appreciated the courtesy which included them in the invitations.

The members of the Boston Local Committees were as follows :

Working Committee—Henry M. Wightman, Chairman, Edward S. Philbrick, Henry F. Walling, Joseph Veazie, Frederick Brooks, and Clemens Herschel, Secretary and Treasurer.

Advisory Committee—James B. Francis, George A. Parker, George H. Norman, Jos. P. Davis, George S. Morison, and O. E. Cushing.

The general programme for each day was arranged and adhered to. It was printed in a handsome pocket pamphlet, interleaved. It is herewith given.

Tuesday, June 18th, Boston Society of Civil Engineers Day. The headquarters of the Society will be at the Hotel Brunswick, on Boylston street, corner of Clarendon. The meetings of the Society will be held at the Massachusetts Institute of Technology, opposite the hotel, in

rooms kindly placed at the disposal of the Society by the officers of the Institute.

The Local Committee on Convention request each member to call at the rooms of the committee, in the hotel, soon after his arrival, and signify which of the excursions he proposes to join, and whether he will attend the convention dinner, so that the committee, being duly instructed. may be able properly to attend to the comfort of all.

The Convention will be called to order at 10 A. M., session, adjournment, dinner. In the afternoon, by invitation of the Boston Society of Civil Engineers, an excursion will be made by rail to Newton Upper Falls, Aqueduct Bridge, Boston Water Works, and return in coaches through some of the suburbs of Boston,

The Committee of the Boston Society having this excursion in charge consists of: William H. Bradley (Supt. of Sewers of the city of Boston), Chairman and manager of the excursion; Edward Sawyer, Engineer of the Newton Water Works; George S. Rice, Secretary Boston Society of Civil Engineers; Desmond Fizgerald. Supt. Western Division Boston Water Works; C. W. Kettelle, Civil Engineer.

Members of the Convention going on this excursion will leave the hotel at 2.20 P. M. Special cars, provided by the courtesy of the N. Y. & N. E. Railroad Company (C. P. Clark, General Manager), will be found in waiting under the Columbus avenue bridge. These cars will be attached to the train leaving the Albany depot at 2.30 P. M., and this train is due at Newton Upper Falls at 3.07 P. M. A map, showing the route of the return to Boston, and pointing out objects of interest on the way, will be given to each member. The excursion will return to the hotel in time for supper and the evening session, at 7.30 P. M.

WEDNESDAY, JUNE 19TH.—Boston Day. Mr. H. M. Wightman, Manager of the Day. The Convention will be called to order at 10 A. M. Session.—Adjournment.—Dinner. In the afternoon the Convention will divide into parties, each member electing which he will join. The following excursions have been provided for this afternoon: 1.—To Harvard College and Mount Auburn Cemetery, in charge of Mr. Frederick Brooks, A. B. (Harvard). 2.—To the Art Museum, Natural History Building, Trinity Church, and elsewhere about the City as the party may desire. In charge of Messrs. E. S. Philbrick and H. F. Walling. 3.—To the work on the new system of sewerage, now in progress. In charge of Messrs. E. C. Clarke, Principal Assistant Engineer, and Geo. S. Rice, Division Engineer, engaged upon the work. 4.—To Bunker Hill (by invitation of Hon. Richard Frothingham, President Bunker Hill Monument Association), and to the Navy Yard. In charge of Messrs. Clemens Herschel and Joseph Veazie. It is expected that Mr. Frothingham will meet the party at the Monument grounds. 5.—To the Brighton Abattoir and the Watertown Arsenal. In charge of Mr. H. M. Wightman, Assistant City Engineer. 6.—To the Creosoting Works at South Boston; Mr. E. R. Andrews, Proprietor. In charge of that

gentleman. Members of the Convention going upon one of these excursions will report to the gentleman having the same in charge, in the parlor of the hotel assigned the Convention. Coaches are provided as transportation for those excursions not readily made by the public conveyances. The coaches will start from the hotel at 2:30 P. M. Members especially interested in the construction of dams for storage reservoirs, who may wish to see the dams now building at Framingham, 25 miles out from the City, will report to Mr. G. P. Low, Jr., Assistant Engineer, engaged upon the work, who will guide the party to Framingham and to the Reservoir dams. The train for Framingham will leave the Albany depot at 2:15 P. M. Session and business meeting at 7:30 P. M.

THURSDAY, JUNE 20TH.—Harbor Day. Mr. E. S. Philbrick, Manager of the Day. By invitation of the Boston Board of Trade, John W. Candler, President, an excursion will be made in the Upper and Lower Harbors, including a lunch on board the *Bohemian*, of the Leyland line of Liverpool steamers, Thayer & Lincoln, Agents; and a visit to Fort Warren, &c., as detailed below. The Committee of the Boston Board of Trade, tendering this excursion to the Convention, consists of John W. Candler, Chairman; Alpheus H. Hardy, Henry F. Woods, Curtis Guild, William H. Lincoln, Charles M. Clapp, and Rufus S. Frost, and the excursion will be made on the city steamer, *J. Putnam Bradlee*, kindly tendered through the Board of Trade by the City of Boston, Hon. Henry L. Pierce, Mayor. Members of the Convention going upon this excursion, may take coaches leaving the hotel at 9:30 A. M., for Eastern Avenue wharf (next south of South Ferry to East Boston). The boat leaves at 10 A. M., passing in front of Navy Yard, will enter mouth of Mystic River, and see the Lowell Railroad improvements; will then visit the improvements of the South Boston flats. (See Transactions of the Society, No. CLV.) A landing will here be made. Cross Upper Harbor to Grand Junction wharves, land, inspect railroad facilities and elevator; lunch on British steamer *Bohemian*. The route after lunch will be governed somewhat by the state of the weather. If this should be suitable for going outside, the steamer will proceed to Fort Warren, Col. John Mendenhall, United States Artillery, commanding, where a landing will be made for inspection of the Fort, after which the party will approach Minot's ledge lighthouse,* and return through Hull gut, Weir river and Quincy Bay to the City. If the weather should be unfavorable for going outside, the party will land at Deer Island,* and inspect the public institutions there, before landing at Fort Warren, and return thence via Hingham Bay, as above.

Schedule of time: Leave wharf, 10 A. M., arrive at South Boston 10:30. Leave South Boston, 11:30 A. M., arrive at East Boston, 11:45. Leave East Boston, 1:30 P. M., arrive at Boston on the return about 5 P. M. The steamer's whistle will be sounded five minutes before leaving

* The weather being favorable, both the trip to Minot's ledge and the visit to Deer Island were made.

each landing. In the evening at 7:30, the Annual Dinner will take place at the Hotel Brunswick.

Friday, June 21st.—Lowell and Lawrence Day. Mr. James B. Francis, Agent and Engineer of the "Proprietors of Locks and Canals on Merrimack River," Manager during the stay of the party at Lowell. Mr. E. D. Leavitt, Jr., Mechanical Engineer, Manager during the stay of the party at Lawrence. By invitation of Mr. James B. Francis and others, an excursion will be made to Lowell and Lawrence. Members of the Convention going upon this excursion, may take coaches leaving the hotel at 7:30 a. m., for the Lowell Depot. Train leaves at 8:00 a. m. Special cars and trasportation will be provided for the members of the Convention by courtesy of the Boston & Lowell and Nashua & Lowell Railroads (Hocum Hosford, General Manager). The train is due in Lowell at 9:00 a. m. Opportunity will be given to inspect some of the cotton, carpet and other mills at Lowell, the system of canals and water power of the Proprietors of Locks and Canals on Merrimack River, the processes of gauging running water; the two Lowell pumping engines, &c., with lunch at the engine-house at 0:30 p. m. The train for Lawrence leaves the Merrimack street depot at 2:00 p. m., being due in Lawrence at 2:35 p. m. Opportunity will be given to inspect the Lawrence pumping engine, the water power of the Essex Company, the Washington (woolen) Mills, &c. The train for Boston leaves the North Lawrence depot at 5:00 p. m., and is due in Boston at 6:04 p. m.

Saturday, June 22d.—Mount Washington Railway, and Home. Mr. Geo. S. Morison, Manager of the Day. By the courtesy of the Eastern Railroad Company (Gen. A. P. Rockwell, President), an excursion has been arranged to Mount Washington, returning Monday morning. Members take coaches leaving the hotel at 7:45 a. m. The train leaves the Eastern Railroad Depot at 8:15 a. m., and is due at Fabyan's at 1:40 p. m. Headquarters of the Society at the Fabyan House.

The programme, as printed above, was carried out.

By the kindness of the officers of the Portland & Ogsdenburg Railroad, open observation cars were provided at Conway, and full opportunity was thus given for the enjoyment of the scenery through the White Mountain Notch, and for an inspection of the location and construction of that railroad. From the Fabyan House, where dinner was provided, the train was hauled to the foot of the incline, and there, by the courtesy of the Mount Washington Railway Company (Sylvester Marsh, President), three of the incline locomotives, with the peculiar cars which ascend the mountain, were in readiness and took the party to the summit, and, after a short stay, descended the incline. Spending Sunday, either at the Fabyan House or at Crawford's, the majority of the party returned to Boston on Monday. On Tuesday Fall River and Providence were visited, and interesting engineering works at these cities examined.

REPORT OF THE TREASURER.

Receipts and Disbursements, November 7th, 1877, to May 31st, 1878.

Receipts.

Balance from former Treasurer	$634 67
Entrance Fees	345 00
Dues	5,632 50
Sales of Publications and Diplomas	112 98
Interest Norman Medal Fund	70 00
do Fellowship Fund	280 00
Miscellaneous	25 00
Total Receipts	$7,100 15

Disbursements.

(A) *For liabilities incurred previous to the beginning of the current Society year:*

Publications	$1,440 70	
Stationery	167 55	
Rent	400 00	
Legal Services	160 88	
Janitor, House Repairs and Supplies	142 04	
Postage	1 70	
Miscellaneous	15 25	
		$2,328 12

(B) *For liabilities incurred during the present Society year:*

Publications	$1,053 22	
Rent	800 00	
Stationery and Printing	249 91	
Salaries	1,500 00	
Postage	189 76	
Fuel and Light	229 89	
Annual Meeting	105 75	
Janitor, House Repairs and Supplies, and Library	331 63	
Norman Medal and Prize	128 15	
Telegraph, Express and Contingencies	61 57	
Safe Deposit and Insurance	29 13	
		$4,679 01
Total Disbursements		$7,007 13
Balance		93 02
		$7,100 15

The Board of Direction considered it proper to pay first the liabilities incurred during previous years, running back to 1874, which were found to be due at the beginning of this Society year, and which, as shown above, amounted to $2,328 $\frac{12}{100}$.

These payments have reduced the amount available for current expenditure, which would otherwise have been mostly devoted to publications.

The balance transferred from the previous year was also reduced by the payment during the last month of that year, of bills amounting to over $1,000, which had been incurred during a period extending from December, 1872, to April, 1877.

The Society is now out of debt, excepting perhaps a few bills, not exceeding in amount $250, which have been presented as incurred previous to the present Society year, and which are now waiting adjustment or explanation.

The funds of the Society are safely invested. Should the receipts from the payments of dues by members equal the average of past years, the publications can soon be brought up to date.

J. J. R. CROES,
Treasurer.

LIST OF NEW BOOKS ON

ENGINEERING AND TECHNOLOGY.

Agriculture, Book of ——. A Manual of Agricultural Science, as applied in Practice. W. W. Fyffe. London. Post 8vo. *Stewart.* 1s. 6d.

Architecture. Modern Dwellings in Town and Country, adapted to American Wants and Climate. 100 original designs of cottages, villas and mansions; with Treatise on Furniture and Decoration. H. Hudson Holley. New York. 8vo, illus. *Harpers.* $4.00.

Architectural Studies in France. 90 lithog. plates (16 colored). W. G. Davis. London. Imp. fol. *Batsford.* 63s.

Centennial Exhibition Reports. Official Reports of the International Board of Judges, Centennial Exhibition, 1876. Edited by Francis A. Walker, Chief of the Bureau of Awards. 8vo, paper. Group I.—Minerals, Mining and Metallurgy, including the Machinery. Illustrated. 494 pp. $2. Group III.—Chemistry and Pharmacy, including the Apparatus. Illustrated. 292 pp. $1.50. Group X.—Clothing, Furs, India rubber Goods, Ornaments and Fancy Articles. 112 pp. $0.75 Group XIV.—Apparatus of Heating, Lighting, Ventilation, Water-Supply and Drainage. Illustrated. 88 pp. $0.75. Group XVIII.—Railway Plant, Rolling Stock and Apparatus, Road Engines. Profusely illustrated. 94 pp. $1.25. Group XX.—Motors, Hydraulic and Pneumatic Apparatus etc. Illustrated. 432 pp. $2. Group XXV.—Instruments of Precision, Research, Experiment and Illustration, including Telegraphy and Music. Illustrated. 210 pp. $1.00. Group XXVIII.—Education and Science. 392 pp. $1.75. Group XXIX.—Horticulture. 54 pp. $0.25. Groups XXX. to XXXV.—Live Stock. 132 pp. $0.75. Group XXXVI.—Pomology. 50 pp. $0.25. Collective Exhibits. 40 pp. $0.25. A complete set of the Judges' Reports. 32 vols. $20. Philadelphia. *Lippincott.*

Contracts. The doctrines of the law of —— in their principal outlines, stated, illustrated, and condensed. J. P. Bishop. St. Louis. 8vo. *Soule & Thomas.* $3.50.

Drawing; a Treatise on Linear Perspective ——, adapted to the Second Grade of the Science and Art Department. 2d ed., enlarged. J. & G. Yule. London. 4to. *Waterston.* 2s. 6d.

Education; The Year Book of —— for 1878. Henry Kiddle and Alexander J. Schem. New York. 8vo. *E. Steiger.* $2.00.

Geometry. A complete Course of Second Grade Practical ——, including the Elementary Projection of Solids. With numerous Examination Papers; Drawing Book combined. J. & G. Yule. London. 4to. *Waterston.* 2s. 6d.

Heat; The Analytical Theory of ——. Joseph Fourier. Trans. with notes by Alexander Freeman. London. 8vo. *Cambridge Warehouse.* 16s.

Iron, Steel, and Allied Trades in 1877. Annual Report. J. S. Jeans. London. 8vo. *Spons.* 15s.

Light; The Principles of —— and Color. Edwin D. Babbitt. New York. 8vo, illus. *Babbitt & Co.*

Logarithms; New Manual of —— to seven places of decimals. Dr. Bruhns. London. Royal 8vo. *Low.* 6s.

Machine Construction; Principles of ——. Edward Tompkins. Edited by Henry Evers (Collins' Advanced Science Series). Vol. I. London. 12mo, plates. *Collins.* 3. 6d.

—— Construction; Principles of ——. Edward Tomkins (Advanced Science Series). Text and Plates. New York. Text, 12mo; plates, 4to. *Putnams.* $4.50.

Magnetic Variations in the United States; being a compilation of Observations made in America from the year 1640 to the present date. Tabulated and arranged for the

use of surveyors. J. B. Stone. New York. 12mo. *Van Nostrand* $1.50.

Museum—South Kensington ——. What it is; how it originated ; what it is doing for England and the world. A lecture delivered in Cincinnati, April 5, 1878, by Chas. P. Taft. 8vo. *R. Clarke & Co.* $0 25.

——— South Kensington ——. Free Evening Lectures, delivered in connection with the Special Loan Collection of Scientific Apparatus, 1876. (South Kensington Handbooks). 8vo. London. *Chapman & Hall.* 8s.

Nile, The sources of the Nile. Through the dark Continent, around the great lakes and down the Congo. Henry M. Stanley. London. 2 vols. 8vo, illus. *Low, Marston & Co.* £2 2s.

Paris Exhibition, Official Catalogue of the British Section, Paris Universal International Exhibition. 1878. Published by Direction of the President of the Royal Commission. In two parts. Plans and Elevations. Demy 8vo, sd., pp. lxxxvi—284 and 260. London. *Eyre & Spottiswoode.* 2s. 6d.

Pine Plantations on the sand wastes of France. John Crombie Brown. Edinburgh. 8vo, *Oliver & Boyd.* 7s. 6d.

Ponds, A short practical treatise on dew ——, the farmer's summer water suppliers : being invaluable on hilly farms and sheep-runs, self-supporting, need no repair, and always efficient. With two folding plates and diagram. H. P. Slade. London. 8vo, *Spons, New York.* $0.80.

Railroad Builder, A Handbood for estimating the probable cost of American Railway Construction and Equipment. Wm. J. Nicolls. Pocketbook form. Philadelphia. 18mo. *Henry C. Baird & Co.* (Announcement.)

Railway System, Index to our —— —— and our Leading Lines: a comprehensive Analysis of Railway Property. A handbook for shareholders and investors and all who are interested in railway administration and management. W. Fleming. London. Roy. 8vo. *M'Corquodale.* 2s 6d.

Railway Reports, American —— ——; a collection of all reported decisions relating to railways. H. A. Shipman, New York. 8vo. Vol. 9. *Cockcroft & Co.* $6.

Ready Reckoner, Merchants —— ——. Arranged expressly for Coal Proprietors, Merchants, Railway Companies, &c. 4th ed. Folio. *Simpkins.* 4s.

Record of Science and Industry, Annual, for 1877. Spencer F. Baird, New York. 12mo. *Harpers.* $2.

Society of Engineers, Transactions for 1877. Edited by P. S. Nursey, Secretary. London. 8vo. *Spons.* 15s.

Telegraph Cables, Laying and repairing. Capt. V. Haskier. London. Post 8vo. *Spons, New York.* $2.

Tramways, their construction and working, embracing a comprehensive history of the system, with an exhaustive analysis of the various modes of traction, including horse power, steam, heated water, and compressed air; a description of the varieties of rolling stock, and ample details of cost and working expenses, with special reference to the tramways of the United Kingdom. With 9 engravings and folding plates. D. Kinnear Clark. London. Post 8vo. *Lockwood.* 18s.

Trigonometry, The elements of Plane ——. Eugene L. Richards, New York. 12mo. *Appleton.* $0.75.

Water Supply, London —— ——: Being an examination of the alleged advantages of the Scheme of the Metropolitan Board of Works, and of the inevitable increase of rates which would be required thereby. By a Civil Engineer. London. 8vo. *Spon*. 6d.

——— ——— Tidy's Report on the London Water Supply. London. Small 4to. *Churchill.* 2s. 6d.

ANNOUNCEMENTS.

The explanation of the delay in issuing the publications of the Society will be found in the report of the Treasurer, printed in this number.

Discordant Standards of Measurement. —A number of members of the Society desire to obtain for publication, statements of the various discordant standards of measure in use in the United States. It is known that in many cities the old standards are more or less at variance with the present, and that, quite frequently, confusion and annoyance are the result. A table, compiled from the information which is undoubtedly in the possession of members of the Society, would be both interesting and valuable. The request is, therefore, made, that any information which would be of assistance in the preparation of such a table be forwarded to the Secretary. The replies should state the equivalent of the measures referred to in U. S. standard feet or in meters, together with any additional notes which may be applicable. If provisional equivalents, afterwards proving incorrect, have been adopted, the value of these should also be stated.

Members who desire to secure complete sets of the Transactions of the Society are requested to send to the Secretary a list of the papers which are needed to fill up their sets. Some of the earlier papers are out of print. If orders are received for a sufficient number to warrant the expense, a reprint will be made.

Special attention is called to the code of rules for award of the Norman Medal, printed at the end of this number. Papers for competition must be submitted previous to September 6th, 1878. All members of the Society are invited to assist in securing the presentation of papers for this award.

MEMBERS of the Society who expect to visit Europe during the present year, are requested to inform the Secretary as soon as possible of that fact, and also of the time when they purpose leaving and the probable length of their stay abroad, together with their European address.

The following resolution was adopted at the Ninth Annual Convention of the Society and ordered printed regularly in the Society publications :

Whereas, the metric system of weights and measures is now extensively used abroad ; and whereas, it is desirable that the relation of the units of differing systems be made familiar to all, by comparison :

Resolved, That Members be requested, in papers hereafter presented to the Society to write, in parenthesis, weights or dimensions by the metric system in connection with those of the system in general use.

THE HOUSE OF THE SOCIETY is at 104 East Twentieth street, one door east from Fourth avenue, and near southwest corner of Gramercy Park. It is open from nine o'clock A. M. to five o'clock P. M. each business day except Saturday, when it is closed at three o'clock P. M.

THE Library and Conversation Rooms will also, for the present, be open every *Thursday evening*, from 7½ to 10 P. M. Members are invited to avail themselves of the opportunities afforded on Thursday evenings both for consultation of books and periodicals and for conversation.

EXHIBITION OF AMERICAN ENGINEERING AT PARIS, 1878.—The Committee appointed by the Society to prepare this Exhibition presented a report at the late Annual Convention, from which the following information is gathered:

The Exhibition may be divided into two classes: 1st. The drawings and photographs of works which have been grouped in departments and are mounted on the structure erected for this purpose, where they may readily be seen and examined by all visitors to the Exposition, together with the models and specimens which are likewise conspicuously displayed. 2d. A collection of tracings, albums, specifications, blank contracts, lithographs and other miscellaneous matter, not designed for general exhibition, but accessible for inspection to engineers and others who may desire to make special investigations.

The structure on which the drawings, photographs and models are mounted was built for your Committee by Messrs. Mead & Taft, of Cornwall-on-the-Hudson, and taken to France by one of the Government vessels. All parts except the interior frame, which is concealed by the drawings, are of American hard woods. It is an excellent example of first-class machine-made carpenter work, and in itself forms a good collection of our native finishing woods.

This structure is so designed as to cover exactly the amount of space allotted to your Society, namely 16 feet wide by 21 feet long. Its exterior surface furnishes six alcoves, each appropriated to a different department, while additional wall surface as well as a small office is provided in the interior, and a broad staircase leads to a platform above.

The six alcoves have been appropriated to the following general departments;

Foundations and Masonry; Bridge Superstructure ; Hydraulic Machinery ; Inland Marine ; Rolling Stock ; River and Harbor Improvements.

Four of these alcoves are at the corners of the structure, and each of them affords three vertical wall spaces 3 feet wide by 5 feet high, two inclined spaces 3 feet square, and one smaller triangular space. The alcoves devoted to Bridge Superstructure and to Foundations are in the middle of the long sides and twice the size of the others. There are also upon the wall spaces not included above, photographs and drawings representing Elevated Railroads and Gas Works.

The Committee hope to be able to arrange for the preservation of the structure and the collection mounted in its alcoves, as a permanent exhibit of American Engineering; it may be placed after the close of the International Exposition in the Museum of the *Ponts et Chaussees.*

The expenses incurred to date amounted to $1,103.51.

Of this amount, about $350 is for framing and mounting the contributions of individual exhibitors. A part of the money so spent has already been returned by the exhibitors, and the expenses, as stated above, are stated as reduced by the sums so repaid. The Committee hope that all exhibitors will see the propriety of paying the cost of preparing their contributions for exhibition, and that nearly or quite all of the $350 will be returned in this way.

The contributions to date amounted to $972, and were made by fifty-two individuals and firms, while the Society comprises nearly 600 members.

The Committee originally estimated the expenses of the Exhibit at $1,500, but believed it important to raise $2,000, which sum will enable them to publish a small volume descriptive of the Exhibit, with brief historical articles on American Engineering.

The Committee, believing that they are really doing an important work, which as yet is hardly half completed, appeal to the Society and to all who are interested in American Engineering for additional contributions.

After the presentation of the report, it was ordered by the Convention that a subscription paper should be prepared and submitted to Members of the Society, which has been done. The following clause is from this paper:

Your Committee, thoroughly convinced of the importance of raising additional funds, now send the enclosed subscription blank in accordance with this vote. They would call special attention to the fact, that they propose to publish a small volume in English and French, which shall be descriptive of the Exhibit, and contain brief historical narratives of different departments of American Engineering. The additional subscription will enable your Committee to publish this volume.

LIST OF MEMBERS.

ADDITIONS.

MEMBERS.

		Date of Election.
BILLIN, CHARLES E.	(Admitted as Junior, April 5th, 1876), Ast. Eng. Geological Survey of Penna., 4039 Locust St., Philadelphia, Pa.	July 3, 1878.
GLOVER, O. L.	Resident Engineer, Oroya Railroad, Lima, Peru	April 3, "
HASELL, BENTLEY D.	317 Broadway, New York	July 3, "
JAMES, SAMUEL L.	New Orleans Pacific R'y, 159 Common Street, New Orleans, La.	May 1, "
KINGSLEY, MARVIN W.	As't Eng. Water Works, 354 Superior St., Cleveland, O.	July 3, "
MELVIN, DAVID N.	Supt. American Linoleum Mf'g Co., New Springville, Richmond Co., N.Y.	" " "
RODD, THOMAS	Pennsylvania Company, Pittsburgh, Pa.	June 5, "

ASSOCIATE.

ANDREWS, EDWARD R.	10 Warren St., New York	June 5, 1878.

CHANGES AND CORRECTIONS.

MEMBERS.

ABERT S. THAYER ..... U.S. Civil Engineer, 1907 Penna. Ave., Washington, D.C.
BISSELL, H. ..... Master Maintenance of Way, Eastern R.R., Salem, Mass.
CHANUTE, O. ..... As't Genl. Supt. and Chief Engineer, New York, Lake Erie & Western R'y, 187 West Street, New York.
CHESTER, STEPHEN ..... Room 6, 239 Broadway, New York.
DUNCKLEE, JOHN B. ..... 1907 Penna. Ave., Washington, D.C.
GODWIN, BRYANT ..... 19 East Thirty-seventh Street, New York.

HALL, G. THOMAS.....Charlton, Saratoga Co., N. Y.
HARRIS, ROBERT L.....Chief Engineer, Canada Central Extension R'y, Pembroke, Ontario, Canada.
HAVEN, WILLIAM A.....Chief Eng. Brattleboro, Whitehall R. R., Brattleboro, Vt.
LATCHA, J. A.....Coldwater, Mich.
MERIWETHER, NILES .....Chief Eng., Natchez, Jackson & Columbus R. R., Fayette, Jefferson Co., Miss.
MORSS, FOSTER.....Engineer for Contractors, Shenandoah Valley R. R., Charleston, Jefferson Co., West Va.
NORMAN, GEORGE H.....Newport, R. I.
OLNEY, LA FAYETTE.....33 Niagara Street, Buffalo, N. Y.
SMITH, F. H.....Eng. and Supt., Baltimore Bridge Co., 13 German St., Baltimore, Md.
WURTELE, ARTHUR S. C..D. & H. C. Co., 19 Jay Street, Albany, N. Y.

ASSOCIATES.

PROUT, HENRY G.....Care of Railroad Gazette, 73 Broadway, New York.
WATKINS, CHARLES D....118 East 115th Street, New York.

JUNIORS.

BLAND, JOHN C..... 265 South Fourth Street, Philadelphia, Pa.
BURR, WILLIAM H.....Pawling Avenue, Troy, N. Y.
HAYES, EDMUND.....11 Kremlin Hall, Buffalo, N. Y.
JOHNSON, L. M.....Genl. Mang. Cairo & St. Louis R.R., 520 Walnut Street, St. Louis, Mo.
OSGOOD, JOS. O.....Milton, Mass.
WHINERY, S. .....Civil Engineer, Georgia Avenue, head of Sixth Street, Chattanooga, Tenn.
WHITLOCK, FRANK W.....East River Bridge, New York.

FELLOW.

COIT, EDWARD W.....261 South Fourth Street, Philadelphia, Pa.

DECEASED.

SCHOTT, C. RIDGELY.....Member.....July 9, 1878.

American Society of Civil Engineers.

PROCEEDINGS.

Vol. IV, May, 1878.

MINUTES OF MEETINGS.

(Abstract of such as may be of general interest to members.)

OF THE SOCIETY.

July 3d, 1878.—The Society met at 8 p. m., Vice-President Roberts in the chair.

The ballot upon admission to membership was canvassed, and the following were declared elected as Members: Charles E. Billin of Philadelphia, Pa. (elected Junior April 5th, 1876); Bentley D. Hasell of New York; Marvin W. Kingsley of Cleveland, O.; and David N. Melvin of Staten Island, N. Y.

July 17th, 1878.—The Society met at 8 p. m., Charles E. Emery in the chair.

A paper by Theodore Cooper, entitled "Observations on the stresses developed in metallic bars by applied forces," was read by the Secretary, and discussed by Messrs. Blunden, Bogart, Emery, Melvin, North, Raymond and Yardley.

An interesting set of large scale drawings was exhibited, which had been used at the Institute of Civil Engineers in London to illustrate a paper by Thomas C. Clarke, Member of the Society, and which had been kindly sent to this Society.

OF THE BOARD OF DIRECTION.

May 1st, 1878.—Applications for membership were considered. Appropriations were made. Arrangements for the Tenth Annual Convention were considered. Financial business was transacted and reinsurance of Society property directed.

May 13th, 1878.—Action was taken in reference to the transmission to Members of the report of the Committee on Tests of Iron and Steel. Additional arrangements for the Convention were made.

May 29th, 1878.—Applications for membership were considered.

June 5th, 1878.—Final arrangements for the Convention were made.

July 3d, 1878.—Applications for membership were considered. Appropriations were made.

MEMOIRS OF DECEASED MEMBERS OF THE SOCIETY.

G. W. R. BAYLEY, Member A. S. C. E.

Died December 14, 1876.

George William Read Bayley,* was born at Saratoga, in the State of New York, on the 30th November, 1821.

He was the son of G. W. Bayley, a descendant of the early settlers of New England, and who, at the age of four score years, still survives him.

He early exhibited an aptitude for mathematics, and was sent to the Rensselaer Institute at Troy. He graduated in the class of 1838.

His first employment was immediately after graduation, upon the railway from Albany to Buffalo, in his native State. But his health giving way, he went to sea, and spent two years in a tour round the world.

Upon his return he was employed upon the construction of the State prison at Clinton, New York. It was while thus engaged that Gen. P. O. Hebert, at that time Chief Engineer of the State of Louisiana, tendered him a place as assistant engineer, which he resolved to accept. He took up his residence at Baton Rouge, which was then the capital of the State, and served as Assistant State Engineer, under two chief engineers, in succession, till the year 1852.

The duties of this office were peculiar, and limited to the hydrography of the Mississippi River. Naturally of an investigating turn of mind, he entered upon the discussion of some of the most difficult and abstruse problems of hydrodynamic science. This was the beginning of his study of the physics of the Mississippi.

A new direction was given to his studies by his election as Chief Engineer of the New Orleans and Opelousas Railroad, which office he held for nearly ten years.

* Committee to prepare Memoir, W. M. Roberts, E, L. Corthell, C. G. Forshey.

He then acted as City Surveyor of the City of New Orleans, and was subsequently again chosen Engineer of the New Orleans & Opelousas Railroad, and continued as Superintendent and Engineer till its purchase by Charles Morgan, when he was appointed Assistant Chief Engineer and Superintendent of the New Orleans & Chatanooga Road. The construction of the road from New Orleans to Mobile, particularly the renewal of the bridges on that route, demanded the best efforts of the railroad engineer.

There now occurred a collision of duty, to which the railroad engineer is no stranger, and in which Mr. Bayley lost his position by his devotion to duty. The specifications of the contract in grading the track across the Atchafalaya Basin, were such, that the contractor must lose money, or slight his work. As Mr. Bayley's inflexibility in exacting the proper performance of work, was in the way, he was removed in 1872-3.

It was at this time of relaxation that he wrote the "History of Railroads in Louisiana," a work of great research and labor.

His manuscripts were published in numbers in the "Picayune" newspaper. Thus far it has not been put into more permanent form, though containing reliable information.

When the contract was made by Congress for the improvement of the South Pass of the Mississsppi by jetties, Mr. Bayley was selected by Capt. Eads as Resident Engineer, and as such, continued till his death. He was a believer in the ultimate success of this method of obtaining deep water to the sea.

Mr. Bayley's professional papers are marked by solidity and research. He wrote the article on the Mississippi in "Appleton's Cyclopedia." In 1875-6, he served the Louisiana Levee Company, as Engineer and Commissioner of Levees, concurrently with the duties of Resident Engineer of the jetties, which functions he held till his death. He there prepared the article upon "Levees," for "Johnson's Cyclopedia," and the one upon the same subject, published since, in the Transactions of this Society.

Mr. Bayley undertook too much, and overestimated his health. He was for three years a member of the Board of Health for New Orleans, 1873 to 1876, and as such, entered with much earnestness into the question of disinfection. To him, as the auxilliary of Dr. White, is due, more than to any other citizen, the exemption of the city from epidemics. He wrote an able paper analyzing the results of the use of disinfectants.

Mr. Bayley was a member of the House of Representatives from the City for two years, 1874-6; and was an active and efficient legislator. At the same time he was serving the jetties of the South Pass as Engineer, and was Engineer and Commissioner of Levees. Each of these might have been the business of one man. *All*, were more than any man could discharge without taxing inordinately his powers. Doubtless they told upon his constitution, and aided to undermine it.

It will be seen that Mr. Bayley's was a very active and busy life, and

that, for nearly the whole of his thirty years in Louisiana, he was engaged with public trusts and great enterprises.

Mr. Bayley's habits of life and demeanor as a citizen were above reproach. Interested in all that transpired, yet never mingling in the exciting contests of politics ; and like most men of his religious persuasion, he was singularly free from all excesses in word or deed. He was a firm believer in the doctrines of the "New Jerusalem" church, as taught by Emanuel Swedenborg.

Mr. Bayley was twice married, first in 1842 in New York, and again, in 1851 to Miss Harriet Laws of Atakapas, La.

For a few days prior to his death, he felt unwell, and did not go to his office duties, but sent for his MSS. to finish an article he was preparing for this Society.

He died quite suddenly, December 14th, 1876, leaving a reputation and example of a pure and devoted life.

JAMES P. KIRKWOOD, Member and Past President A. S. C. E.

Died April 22d, 1877.

James P. Kirkwood,* was born in Edinburgh, Scotland, March 27. 1807. He was put to school very early, in 1815 was sent to an academy at Galashiels, and in 1818 to Rotterdam, Holland, and returned home after the lapse of a little over a year, having acquired considerable fluency in the Dutch language, and some knowledge of French. He now entered his father's store, where he remained till the fall of 1821, when he was apprenticed to Thomas Granger, land surveyor, who soon associated with himself a Mr. Miller, the firm acquiring a large practice as civil engineers. Mr. Kirkwood served the first term of his apprenticeship, and remained with the firm as an assistant till early in 1832, when he began business for himself in Glasgow, but thinking that the opening for a civil engineer was better in this country, he came here in the summer of the same year. Provided with letters to Wm. Gibbs McNeil (then and for a long time subsequently a railway engineer of the largest practice), he commenced under McNeil with the location of the Norwich & Worcester Railroad ; was thence transferred to the Boston & Providence Railroad, and subsequently to the Stonington & Providence Railroad as Resident Engineer. Still later he became the Resident Engineer on the Long Island Railroad, which was opened to Hicksville in 1837. In 1839 he was engaged on the preliminary works of Flynn's Knoll Light House, New York harbor, under the orders of the U. S. Engineers. This was a most laborious work, requiring his residence at the quarries in the State of Maine for a great part of the time, alternating with his personal supervision of the construction of the coffer dam and foundations in the harbor. The storms of the winter damaged the works very

* Committee to prepare Memoir, A. W. Craven, J. W. Adams, Wm. E. Worthen, Jas. B. Francis.

seriously, and the Government suspended operations, which have never been resumed,

In the spring of 1840 his services were called for on the mountain division of the Western Railroad of Massachusetts, on which he was engaged as Resident Engineer until its completion, in the fall of 1843. Between this date and his taking charge of the location and construction of the Springfield and Northampton Railroad, he was engaged in the preparation of plans and construction of the Delavan House, in Albany, at that time regarded as a work of some magnitude. His health requiring a more genial climate, led to his acceptance from the U. S. Government of the position of Engineer for the Construction of Docks, Hospital, Workshops, and, in fact, all the appurtenances required in a great naval depot, then projected at Pensacola, Florida. He continued on this work until the suspension of the appropriations by the Government for its continuance, in May, 1847. The New York and Erie Railroad having undertaken the construction of a stone arched viaduct on the line of that road, of 16 arches, of 50 feet span each, and 100 feet high, and it being apparent that unless it was built in one season, the opening of the road for travel would be seriously delayed, he was solicited to take charge of that work as Superintendent, and carry it to completion by days' labor, which he accomplished in December, 1848—an unprecedented piece of work to be accomplished in one working season. This led to his appointment as General Superintendent of the Erie Railroad, and in this position he introduced many radical changes, resulting in great improvements in the running of the railroad, and which have been adopted on other roads in this country without acknowledgment—notably, the running of trains by telegraph, introduced by him. His determination to make this great road, so far as the operation of his department tended, what, from it leading position in connection with the West and the great metropolis, it was designed to be, led to opposition from men in office, who did not possess the breadth of view essential to the appreciation of the scope of his efforts; and failing the proper support from them, he resigned the charge of the road to accept the position of Chief Engineer of the Missouri Pacific Railroad in 1850. Perfecting the surveys and construction of that road as far as the means of the company permitted, he returned to New York in 1855. Still retaining connection with that road as Consulting Engineer, he took charge under the Croton Department of the work of lowering and moving horizontally the great water main in Eighth avenue into a rock cut, without cutting off or interrupting the supply of the water to the city through the main—a work of great delicacy. In June, 1856, he received the appointment of Chief Engineer of the Nassau Water Works, Brooklyn, and continued in the office until its completion in 1860. He visited Europe at this time on account of his health, and remained a winter in the south of France, but with little permanent benefit. Unwilling to lose the benefit of his advice in the first management of the work, the Commissioners of Nassau Water Works

wished to retain his services as Consulting Engineer, which he accepted only on condition that it should be without salary. During this time he investigated and reported upon the subject of lead poison in water pipes, and held very positive views upon that subject. He was consulted by the Erie Railroad Company in reference to the Bergen Tunnel, at Jersey City, which he completed, as also on the arrangements of ferries and Long Dock. He served as Commissioner (1859) on the raising the High Bridge at Carmansville Croton Aqueduct; also, in 1860, on a commission for location of terminal depot at Hunter's Point, Long Island Railroad. He reported to the Long Dock Company, on a system of docks and ferries, embracing elevators and floating docks of iron for the reception and handling of grain. Again his health, in 1863, required him to travel, and in 1864 he devoted some time to the Murray Hill distribution, Croton Water Works; and with Messrs. G. R. Baldwin and J. W. Adams, made an examination and report on the entire line from Fishkill to Boston, of the Boston, Hartford and Fishkill Railroad. He was also consulted on the location of high service reservoirs and pumping engines at High Bridge, Croton Water Works.

In March, 1865, he made extensive examinations and exhaustive report on the subject of the Water Works of Cincinnati; and also, in the same year, made similar examination and report on the Water Works of St. Louis, the Water Commissioners of the latter city authorizing him to visit Europe, and examine and report upon the various methods of filtering water for city use pursued in the cities of Great Britain and the Continent. He returned in September, 1866, and the result of his labors appears in an elaborate published report, with copious illustrations of the methods pursued in the principal cities of Europe for purifying city water. This work serves as a text-book for engineers in this branch of hydraulics. While in London, on this visit, he examined and reported to some interested citizens of New York, upon the underground railways of London, and their working. He also reported on the Bergen Tunnel, and returned to St. Louis to examine and report upon the location of pumping stations for that city, with settling basins and a high reservoir service, the basis of the present water work construction for that city. Being offered the position (April, 1867) of Chief Engineer, to carry out his plans, he declined, accepting the position of Consulting Engineer, with the privilege of making his own selection of Chief Engineer and Assistant, being responsible for the work, but retired from the immediate supervision. All the important structures were built from his designs, or plans approved by him. This embraced the pumping engine and specification for the same. At this time he was consulted on the designs of the third Ridgewood engine, Brooklyn Water Works, and it was designed under his direction.

In 1868, still in the employ of the Water Commission of St. Louis,

he was consulted on various water works—Pittsburg, Pa., Portland, Maine, and Salem, Mass.

In 1869 he reported on the extension of the Brooklyn Water Works by the construction of additional reservoirs. In the same year he was appointed Consulting Engineer of the Water Works of Poughkeepsie, N. Y.; in 1870, of the Water Works at Lowell, Mass.; in 1871, of the Water Works at Fall River, Mass.; in 1873, of the Water Works of Lawrence, Mass. In 1872 he made a report on the additional supply of water for the city of Albany, N. Y., and afterwards had charge of the construction of the works. In the same year he drew up the specifications for the construction of the storage reservoir, Hempstead, L. I. In 1873 he made investigations and report on new water works for Hoboken and Weehawken. In 1874, in conjunction with Mr. James B. Francis, he made a report on the additional supply for the city of Boston, and in the same year an examination and report upon the drainage of the low lands in Hoboken, involving the use of pumping machinery to lift the contents of the sewers to the level of tide. In 1875 he made an extended examination and report to the Massachusetts State Board of Health on the pollution of rivers. In 1876 he made a report on the necessity and means of economizing the water supply of Lynn, Mass.

The above list of reports made and works constructed is necessarily imperfect. In the earlier years of his practice, Mr. Kirkwood kept a diary, but latterly the memoranda were desultory and imperfect. The list is, therefore, made up from published reports, and from the recollection of your committee, who were all more or less associated with him in business. He was often on commissions for the testing of pumping engines, for advice on constructions, and few of the water works for the large cities have been undertaken or carried out without consultation with him.

In Mr. Kirkwood's life may be traced the beginning and growth of our engineering profession. He commenced in 1821 by entering the office of a land surveyor, when the distinction of civil engineer was hardly known; he began with dragging the chain and the usual office work of the land surveyor; but in the call for further works the land surveyors became a firm of civil engineers, with large practice in railways and canals. By 11 years of industry with this firm Mr. Kirkwood had acquired a practical knowledge of the profession as it then was, and after a short trial by himself in Glasgow he started for this country, where he trusted his knowledge might be of value. In this he was not disappointed; from the valued assistant of Major McNiel he passed to the charge of varied works—filling most important offices, especially in the department of railway engineering, in which he occupied, at times, different grades and duties, as assistant, chief and consulting engineer, once on the Missouri Pacific, as contractor, and lastly on the Erie railroad, acting as General Superintendent and taking charge of the running of the road. Up to 1855 Mr. Kirkwood's labors were almost entirely con-

fined to railway engineering, and he was considered at the head of his profession. Having been called, by Mr. A. W. Craven, to the charge of some work in the Croton Department, which was successfully executed, on the determination of the City of Brooklyn to construct water works he was made the Chief Engineer. With this appointment his attention was almost entirely diverted to water works for the supplies of cities and towns. This branch of the profession, at that time, was but little studied, and its demands very limited, but Mr. Kirkwood brought to it that wonderful perseverance and industry which had given him his position in the railway branch. His life had always been an eminently practical one; there were no schools in his youth where even the rudiments of the profession could be studied; public works which might serve for precedents were few and the knowledge of them but little diffused. Soon the demands of the times and the needs of the profession increased beyond the precedents; works were undertaken and constructed on the basis of the best common sense of the time, and the theory of construction followed after. When he entered upon the construction of water works for cities, as in his first commencement on railways, examples were few, and the literature connected with this branch very meagre. Mr. Kirkwood made thorough inspection of what had been done, both here and abroad, and secured all books pertinent to the subject; he has left constructions which will long stand as precedents, and has enriched the literature by valuable memoirs and reports. From his nature and education he was eminently conservative, and it required strong proofs of economy in construction and maintenance to make him give up old and well tried modes or machines. He never adopted a theory merely because it was novel, or to obtain credit for its introduction; nor made expensive experiments at the cost of parties employing him. Safety was a large factor in his constructions, and he preferred the credit of doing better what had already been executed to striking out new and uncertain paths. Yet, with a full knowledge of precedents, it was not a blind following, and the improvements introduced by him have been many and gradual; the growth was strong and natural. He early introduced the coating of water mains, and the improvements of pumping engines have been largely due to his approval. During the last 25 years of his life Mr. Kirkwood was an invalid, but the works undertaken during that time show no feebleness in design nor execution, and in number and importance they exceed those of any other engineer in his line in the country. Called as an advisory engineer on the Lynn Water Works, near the close of his life, and confined to his hotel by severe cold weather, the President of the Board remarked, after an interview with him, "that it was a wonder to him that one so reduced in strength could command the great store of facts and principles his life time had gathered and so readily apply them to the matter in hand," and this we think to have been the universal sentiment with all those with whom he was brought into contact. He

gave the conviction of a thorough knowledge of his subject, acquired by long practice and extended reading, and a sterling honesty, in the statement of his views and recommendations.

Mr. Kirkwood was the second President of the American Society of Civil Engineers, and well known to most of its members, and especially to the members of this committee—life time friends who, from their intimate relations with him, both professionally and socially, could appreciate him, both as an engineer and as a man with a professional knowledge based on strong common sense, and extended by close observation and unwearied industry; he was extremely sensitive about placing himself under any financial obligations, and modestly underrated the value of his own services. The counsel of no one could be more safely trusted than that of Mr. Kirkwood, as he had the elements which go to make up a safe counsellor—modesty, capacity and integrity.

CHARLES S. EMACK, Member A. S. C. E.

Died July 26th, 1877.

Charles S. Emack* was born in April, 1834, in the Town of Lambertville, New Jersey, and died July 26th, 1877.

He had the advantages of a good education, under the instruction of the late Samuel H. Parsons, a thorough teacher, and practical mathematician.

In 1852 or '3 Mr. Emack was taken on to the Belvidere railroad by Mr. Ashbel Welch, and continued thereon during its construction.

In 1857 Mr. Emack entered the service of the Hazleton Coal and Railroad Company, under Martin Coryell; but his health was not sufficient to withstand the laborious work of mountain surveys, and the damp underground work of the mines, and he left, to find more congenial employment under Mr. Thomas Seabrook; and in January, 1859, entered, in the capacity of a *rodman*, upon the surveys and estimates of the Pittsburgh & Steubenville, and Chartiers Valley, Hempfield, Marietta & Cincinnati Railroads, and two or three other lines or branches of railways.

In 1861 Mr. Emack took charge of the Steubenville extension of the Pennsylvania Railroad, as principal Assistant Engineer, and left, in 1865, to take charge of the masonry on the connecting railroad of Philadelphia, and remained until the completion in 1867.

In 1868 he went with Mr. Thomas Seabrook to Baltimore and acted as Chief Engineer of the Baltimore & Potomac Railroad.

In 1872 his health so failed him that he had to resign his charge and seek rest and quiet.

In so doing he sought the mild climate of Virginia, and there found a wife who was willing to take upon herself the care of an invalid, and

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* Committee to prepare memoir—Martin Coryell, G. Leverich.

those who knew the kind disposition and the sterling integrity of Mr. Emack are not surprised that his declining health found a kind and sympathising heart to share with him the burdens of life.

Mr. Emack was not conspicuous as an engineer beyond the immediate vicinity of his work, but his faithful attendance to the duties assigned him ever commanded the respect of those with whom he was associated.

Had his health been spared he would have contributed largely to the general information of our profession, for his industry and indefatigable zeal filled his note books with facts and figures and the practical results of every day's experience in interesting works.

ROBERT L. COOKE, Member A. S. C. E.

Died August 11th, 1877.

Robert Latimer Cooke,* was born at Williston, Vermont, on June 27th, 1809. He was graduated at Middlebury College, in his 18th year, and afterwards was admitted to the Bar. He soon, however, surrendered the practice of law and devoted himself to teaching, first at Stanton, Virginia, and afterwards for twenty years at Bloomfield, New Jersey.

He then entered the service of the Lehigh Coal and Navigation Company, as an Assistant Engineer, and for a number of years was employed in surveys of the lands of the company, and the construction of its roads. A history of this company and its works was contributed by him to the Society, on April 19th, 1876. Subsequently he held the position of Superintendent of Construction of the Lake Champlain & Moriah Railroad, in the State of New York.

In 1871 he was appointed an Assistant Engineer on the Topographical Surveys of the southern portion of Westchester County, since annexed to New York City. This work was under the control of the Department of Public Parks, and he remained in the employ of that Department as a Division Engineer, on the laying out of the new wards, and later as assistant in the preparation of plans fer a new iron bridge across the Harlem River, until his death, which occurred on August 11th, 1877, and which was caused by his being washed overboard in crossing Fire Island bar, on the Long Island coast.

Mr. Cooke possessed extraordinary vigor, both mental and physical, an unusually cheerful disposition, and a warm and affectionate heart. His industry and earnestness in any work on which he was engaged, were the natural results of the conscientiousness and deep religious principles which actuated his whole life. Whatever fell to his lot to perform, was done carefully, intelligently, and thoroughly. His hours of relaxation

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* Committee to prepare memoir, J. J. R. Croes, C. R. Schott, G. Leverich.

were spent in what, to many younger and less active men, would have been arduous work. During the last two years of his life he devoted his evenings to the illustration of a work on Conchology, by finely executed pen and ink drawings, and to the last he kept up the reputation he had deservedly acquired among his friends, of an accomplished and thorough musician.

He was elected a member of this Society April 17th, 1872, and always displayed great interest in its progress and the preservation of a sound policy in its management.

WILLIAM B. OGDEN, Fellow A. S. C. E.

Died August 3d, 1877.

William B. Ogden* was born in Walton, Delaware County, New York, June 15th, 1805, and died August 3d, 1877, at Boscobel, New York City. Descended from parents and ancestors distinguished for their intellectual and social characteristics, as well as honorable official positions, Mr. Ogden naturally began to value mental culture when quite young. With a remarkably vigorous and healthy body, and the usual fondness for boyish sports, he early manifested a love of study, and was preparing to enter college with the view of making law his profession when, at the age of sixteen, he was compelled, by the death of his father, to change his plans. He at once took charge of the family estate, and exhibited extraordinary prudence, judgment and energy in the management of affairs.

He supervised the cutting down of large tracts of timber in his native county, and the floating of it down the Delaware river to Philadelphia. This and other business transactions brought him in contact with some of the leading men of the day, and gave him more enlarged views of the commerce and condition of the country than most persons of riper years possessed. At that time a journey on a raft from Delaware County to Philadelphia was a much more formidable affair, as regards time and danger, than a voyage across the ocean is now. Then there was not a mile of railroad in the country, and but few portions of it possessed good turnpikes. Canals and steamboats existed to a very limited extent.

At eighteen, Mr. Ogden was made Brigade Inspector of the State militia, and continued to serve as such for several years. At twenty-one he was received into partnership by an important commercial house. At twenty-nine he was sent to the Legislature of his native State, and made masterly efforts to secure the construction of the Erie Railroad. Although the bill did not pass that session, it did the next.

Mr. Ogden's comprehensive views led him to see much farther than

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* Committee to prepare memoir—E. S. Chesbrough, George S. Greene, John Bogart.

most men into the future wants and condition of the country. His faith in the early and rapid opening up of the great West was such that he invested largely in real estate in Chicago, to which place he removed his residence in 1835.

The same effective participation which Mr. Ogden took in public affairs in the East did not diminish when he removed West, and it naturally made him very popular, so that when Chicago was first incorporated as a City in 1837, he was elected Mayor. He looked carefully into such projects as promised to benefit his adopted City and the Southwest, and was specially active in encouraging the construction of the Illinois & Michigan Canal.

He took the most prominent part in the commencement of the Chicago & Galena Railroad, and pledged his private fortune, with one or two others, for its completion as far as Elgin, when capital was exceedingly scarce in the west, public faith in the financial success of the undertaking discouragingly weak, and the opposition of supposed rival interests very strong. When the panic of 1836–7 prostrated public and private enterprise, Mr. Ogden was suddenly overwhelmed with a crushing load of obligations he could not meet, owing to the greatly depreciated value of his property. His sense of honor and integrity, however, and the confidence of his friends in him, was such that in a few years he met fully every claim against him. He also exerted his utmost influence by public addresses and private conversation, to arrest the almost universal tendency to repudiate State and municipal indebtedness, and had the satisfaction of seeing his views prevail.

During the long prostration of the West, between 1837 and 1843, Mr. Ogden's hopefulness of a prosperous future did not desert him, but led him to great activity in devising both public and private enterprises, and aiding to carry them out. He labored successfully with those who caused a resumption in 1843, of work on the Illinois & Michigan Canal, which was completed in April, 1848. He also succeeded, by the purchase of an old Indiana charter, in establishing the first connection eastward of Chicago, by railroad, under the auspices of the Michigan Southern & Northern Indiana Railroad.

In 1847 he negotiated the charter and assets of the Galena & Chicago Union Railroad Company, and became its president. In the further extension of this road to the Mississippi, when the stock was greatly depreciated in value, and many owners among the farmers were smarting under their losses, so that it was considered imprudent for a director of the road to go among them, Mr. Ogden and his companions boldly ventured along the line addressing meetings of farmers and others on the importance and value of the work, and succeeded in obtaining many new subscriptions. When this road was first commenced there was a very large retail trade in the City kept up by means of wagons, called "prairie schooners," five acres of which would be sometimes encamped together. Lines of stages were also profitably employed. The mer-

chants engaged in this trade, and the owners of the stages and wagons, all thought they would be greatly injured by the loss of their business, but Mr. Ogden had the gratification, in a few years, of seeing that most, if not all, of those persons had been benefited by the construction of the road. The rapid growth of the City greatly increased business, and the stockholders of the company received annual dividends of upwards of twenty per cent. during the first seven years after the completion of the road.

In 1853 Mr. Ogden visited Europe, and remained about a year and a half. While devoting much of his time to art and æsthetic culture generally, his deep interest in public works did not diminish. He made a special study of the canals of Holland, and became more than ever impressed with the importance of so enlarging and deepening the Illinois & Michigan Canal as to make it navigable for steamboats suitable to ply between Chicago and New Orleans, a work which, in connection with the Illinois river locks and draws, now partly constructed by the State, must yet be completed before our national system of improvements can be considered perfect. He also advocated, in 1854, through the Chicago press, the construction of a ship canal across the southern portion of the Michigan peninsula.

In 1855, Mr. Ogden was made president of the newly formed Board of Sewerage Commissioners of Chicago, and remained in office long enough to see the present system of drainage for that City adopted, and so far carried out as to show its beneficial action, and cause the community to urge its further extension as rapidly as means would permit.

At about this time Mr. Ogden was made president of the Chicago, St. Paul & Fond du Lac Railway Company. Considering the magnitude of this work, and the financial disasters of 1857, probably no enterprise Mr. Ogden ever engaged in taxed his time and resources more than this. In 1857 he found himself under personal obligation to pay debts of the company amounting to $1,500,000. The value of the stock disappeared, and a foreign negotiation of bonds, supposed to have been effected, fell through. At such a time it was impossible for him to raise so great a sum of money, but he unreservedly placed the whole of his large property in the hands of the creditors of the company. Friends and family connections placed theirs also at his disposal, and the result was a full payment of the claimants, and the saving of Mr. Ogden's private fortune from ruin, though with a very considerable loss to him. During his connection with this road Mr. Ogden constructed sixty miles of it, from Janesville, north, in fifty-eight days, a feat never previously performed in the history of such works. While constructing this road Mr. Ogden saw that it was likely to enter into disastrous competition with the branch system of the Chicago & Galena Railroad, and used all his influence to bring about a consolidation of the two companies, finally succeeding, in 1864, thus greatly increasing the importance of the Chicago

& Northwestern Railroad Company, which now owns and operates over 2,000 miles of road, and into which the Fond du Lac road had previously been merged.

So great were Mr. Ogden's qualifications as a manager of railroad interests that while director of the Fort Wayne & Chicago Railway Company in 1859, he convinced the owners of the then fragmentary lines, now forming that one road, of the necessity of consolidation. This required the appointment of a receiver during the pendency of the proceedings necessary for the union, and Mr. Ogden was offered a salary of $25,000 to accept the office. This he declined on account of other very weighty public and private obligations ; but upon being told that it was impossible to agree upon any other name than his, he accepted the office, refusing, however, the munificent salary.

In 1850, Mr. Ogden was chosen president of the National Pacific Railroad Convention, at Philadelphia, and afterwards, upon the organizing of the Union Pacific Railway Company, he was elected its first president. He also continued a firm believer in the practicability and final success of the Northern Pacific Railway, with which he was officially connected from the commencement, and actually passed, in company with the Chief Engineer, Col. Roberts, along a considerable portion of the proposed route ; on the Atlantic side, from Lake Superior to the Missouri river, and on the Pacific side from the mouth of Snake River *via* the Columbia Valley to Puget Sound.

Mr. Ogden had an honorable and important connection with other public works than those already mentioned. He was also a friend of religious, literary, scientific and benevolent institutions, contributing liberally for their support during his life, and leaving what will amount to a large sum, to be expended in a similar manner by his administrators.

Mr. Ogden was engaged to be married when quite young, but the decease of the lady prevented the union. His large fortune, and the residence with him of one or more of his sisters, enabled him to exercise a hospitality becoming the high position he held, socially and officially, as very many foreigners and visitors from other parts of our own country have known. His cultivated taste enabled him to furnish his home with every desirable comfort and adornment. Men of distinction in every profession, and from nearly every land, were entertained as his guests, with ease and dignity, He was perfectly accessible to men of the humblest stations, and never repelled any who had the least claim to his time or consideration. At seventy he married Miss Arnot, of Elmira, New York, who was in every way suited to be the companion of so rare and distinguished a man. She still survives him and resides at Boscobel, which Mr. Ogden had made his home during the last ten years of his life, having removed from Chicago to New York on account of very important private interests which demanded his personal attention, but he kept up his Chicago home and residence until the fire of October, 1871.

What has already been said of Mr. Ogden is fully sufficient to show that he was one of that small class of men to whom engineering is more indebted than to all others for its wonderful progress in our country. His great physical and mental power, his extraordinary training, his courage, hopefulness and high sense of honor, and his dignified, yet affable bearing eminently fitted him to be the leader of whatever enterprise he took an interest in. It was by no means, however, so much Mr. Ogden's object to obtain control of works he was connected with, as to make them succeed, in which case he was content with any position from that of simple advocate, to being the principal. Even his vast and masterly arranged private schemes were such as to benefit the public either directly as sources of employment and profit to thousands, for instance, the Peshtigo Lumber Company, or the Brady's Bend Iron Works; or they were to show the public what could be done in certain much needed directions, as well as to accommodate his own business, such as the small, but first outside harbor of Chicago.

It was natural that one of such great ability and experience should be much consulted in relation to enterprises with which he had no official connection. Among these was the first Chicago Lake tunnel, a work which he was one of the earliest to approve and offered to publicy advocate it, if necessary, for its adoption by the city authorities.

True greatness is often proved by adversity. Mr. Ogden had his full share of opposition, detraction and disappointment. Plunged sometimes from superabounding wealth to sudden inability to meet his obligations, he found it difficult at times to pay his table expenses, yet few of his intimate friends seemed to be aware of it. In a day, stripped by the great fires of Chicago and Peshtigo of a million and a half of dollars, and left without income sufficient to meet his taxes, he spoke with great confidence to his fellow sufferers of the prosperous future of Chicago and the West; and encouraged them to go forward in rebuilding the city.

Mr. Ogden was repeatedly urged to be a candidate for high political honors, and was naturally fitted for the highest, but his chosen course of life, as already mentioned, his tastes, and above all his independence of party control, prevented him from accepting positions of this kind unless he saw that in so doing he could serve the interests of the community around him, when he cheerfully performed the humbler duties of City Alderman or those of State Senator.

JOHN F. TRACY, Fellow A. S. C. E.

Died February 13th 1878.

John F. Tracy* died in the City of Erie, State of Pennsylvania, February 13th, 1878. Mr. Tracy was born in that City, January 7th, 1827, he was therefore only a little over fifty-one years old at

* Committee to prepare memoir, W. M. Roberts, M. Courtright, John Bogart.

the time of his death. He became a Fellow of this Society January 20th, 1873. Although thus cut off in the prime of life, Mr. Tracy was associated for a long period with great railroad enterprises, in which he displayed marked genius, enterprise and perseverance, which were crowned with success. He was one of the master spirits among the progressive railroad men of our country, and was largely instrumental in pushing forward the great iron thoroughfares which now carry across this vast continent the commerce between the Atlantic and the Pacific. He was educated at the old Erie Academy, but early in life became an active assistant in the extensive business of his father, Mr. John A. Tracy, who was an eminent contractor, engaged in the construction of canals and railroads. His father built the aqueduct over Walnut Creek, on the Erie Canal, which, at the time—thirty-five years ago, was regarded as a great work. It was eight hundred feet long, and one hundred and one feet high. It was during the prosecution of that work that Mr. Tracy was brought directly under the business training of his able parent, and where he soon exhibited more than usual capacity as a manager, although then but a boy. Subsequently, Messrs. John A. Tracy and Milton Courtright, were associated as contractors in building the Western Division of the Erie Railway, and by them he was employed to superintend the extensive operations of the firm. After the completion of that contract, he was still more actively engaged in the construction of the portion of the Buffalo & State Line Railroad, west of Dunkirk, and of the Erie and Northeast Railroad, and. though not yet twenty-five years old, almost the entire practical management of these enterprises was confided to his care. Very shortly after the completion of the Erie & Northeast road, he was appointed its Superintendent, and operated the road with ability and success. When it was decided to change the gauge of the road and make it part of a through line—a determination which was violently opposed by a large party of citizens in Erie, and which brought on the trouble known as the "Erie Railroad War," Mr. Tracy held his post with firmness and devotion to the interests of his company, and was the only man who never yielded to the pressure of the mistaken popular sentiment which sought to maintain a break in the continuous line of what was destined to become a great continental highway. Mr. Tracy completed the change of gauge, determined on by his own company, and when the work was perfected, in 1854, decided to leave Erie, and accept the position of Assistant Superintendent on the Chicago & Rock Island Railroad, which was then in process of construction. His experience and ability made him an invaluable official, and he was soon promoted to the office of General Superintendent; subsequently was made Vice-President, and finally President of the road, which office he held for many years, and, until compelled by reason of ill health, to resign less than a year prior to his death.

Under Mr. Tracy's management the Chicago, Rock Island & Pacific Railroad acquired a wide reputation. Its bonds were eagerly sought for in every market as investments, and its stock has always continued to pay dividends, and maintains a high price. No road in the country can exhibit a better financial condition, and no act of the Rock Island Company has ever brought discredit to the reputation of American securities. The consequence of this is that the company are able to market their six per cent. bonds at par, and Mr. Tracy always had the unlimited confidence of the representative capitalists of this country and Europe. During the presidency of Mr. Tracy, the Iowa Division was constructed under his management, from the sale of stock alone—a feat unparalleled in the history of American roads. At the same time, while maintaining his position as president of his favorite corporation, the Rock Island, Mr. Tracy secured the control of the Chicago & Northwestern Railroad, and became its president, thereby making himself the direct manager of over thirty-five hundred miles of railroad. He took the position in 1870. After five years service, Mr. Tracy resigned the presidency, suggesting as his successor, Mr. Keep, who is now President of the Northwestern. Mr. Tracy was, while his health remained and his faculties were clear, an expert and successful manager of railroads. He was reticent, determined, and, above all, self-reliant. His roads were managed with a faithfulness and economy rarely equaled. In his business projects he was successful, and during the thirty years of his active life he did his full share in the development of the railway interests of this country, and for the perfection of the American system of railway organization.

With his immense influence in the commercial world, Mr. Tracy was always a quiet, unassuming man, who neither sought nor cared for notoriety.

When Mr. Tracy first assumed official position upon the Chicago, Rock Island & Pacific, its terminus was at Rock Island. Under his management it was extended across the State of Iowa to Council Bluffs, and branches were acquired or leased, so that now over a thousand miles are operated by this Company. The Chicago & Northwestern was also, under his administration, extended from Madison, Wisconsin, to Winona, on the Mississippi River, and a large portion of the branch from Winona to St. Peters was built, as well as the air-line from Milwaukee to Fond du Lac. While upon the Rock Island road, with characteristic energy and pertinacity, he fought to successful issue the contest with the river interest, headed by the St. Louis Chamber of Commerce, which was opposed to the bridging of the Mississippi River; and thus secured a national recognition of the doctrine that navigable rivers, though hitherto protected from all obstructions, must permit bridges to be built across them for the accommodation of those other great commercial highways, the railroads.

In his private life, Mr. Tracy was one of the least ostentatious and most kind hearted of men. His large wealth was bestowed generously in public and private charity.

The intense application to business which was Mr. Tracy's prominent characteristic, began, some years since, to wear upon his physical health. About a year ago his sufferings increased so that business was absolutely forbidden by his physician, and he resigned the presidency of the Rock Island Railroad, and gave up all participation in financial affairs.

In the course of nature, ere many years, all the pioneers of our great works of public improvement will have passed away. It is well to record among the annals of our Society, however briefly and inadequately, some account of our members who have held an honorable place among them.

P. PORTER POINIER, Junior A, S. C. E.

Died June 11th, 1876.

P. Porter Poinier,* only son of Elisha B. and Frances A. Poinier of Newark, New Jersey, died in the City of New York, June 11th, 1876, aged 23 years.

He was a student in the Rensselaer Polytechnic Institute, Troy, during the scholastic year 1871–2, after which he entered the Stevens Institute of Technology, Hoboken, from which he graduated with honor in 1874. During the following year he pursued his studies as post graduate and lecturer to the senior class in the Institute on Thermodynamics.

He became a Member of this Society March 3d, 1875, and took great interest in its welfare and success. He was enthusiastic in the study of abstract and applied mathematics, and had almost a passion for making original investigations, and to aid him in these directions he secured quite a library of rare and valuable foreign works. He finally concentrated his labors upon his favorite subject, that of dynamics of heat, and had gone to Cambridge to superintend the publication of his work upon this subject, when he was suddenly prostrated by a disease which had been preying upon him, and which was pronounced incurable. His ambition was strong, and aims high; and he had already brought himself to the notice of the learned. The trustees of the John Hopkins University, Baltimore, appointed him to a Fellowship in that institution, the certificate for which reached his friends only the day after his death; and Prof. William Thompson, in his recent address before the British Association for the Advancement of Science made honorable mention of him as a young investigator and promising student.

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* Committee to prepare Memoir, R. H. Thurston, DeVolson Wood.

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From C. Latimer, Cleveland, O.:
Proceedings of Meeting of road masters of the Atlantic and Great Western R. R. Nov. 15th, 1877.
Comparative Statement of Expenses in Engineering Department of the A. & G. W. R. R. December, January, February, 1877-8.

From G. Leverich, Brooklyn, N.Y.:
Memorial relating to tests of Experimental Guns. Leverich and Mann. Washington. 1878.

From Charles Macdonald, New York:
Illustrated Album of the Delaware Bridge Company. 1878.

From Edward Marsland:
Photographs of U. S. Dredge Boat, "McAlester;" of the engines of the "McAlester;" of the engines of the "Geo. W. Elder;" of

double engines by Rowland; of the New York Caisson of the East River Bridge. 7 Photographs.

Engravings of the U. S. Dredge Boat, "Essayons;" of the P. & S. Steamer, "Massachusetts."

Description of the Marsland Water Meter. E. Marsland. Philadelphia. 1876.

From W. Ripley Nichols, Boston:

On the Filtration of Water. W. R. Nichols, Boston. 1878.

Die Stadtische Wasserversongung. 1 Band. Statistik Beschreibung der Anlagen in Bau und Betrieb. E. Grahn, Munchen. 1878.

From the North of England Institute of Mining and Mechanical Engineers, Newcastle-on-Tyne:

Transactions of the Institute, February, March April, 1878.

From Charles Paine, Cleveland, O.:

Miles run by Engine, Tender and Passenger equipment, and Wheels removed during 1877. Lake Shore and Mich. Southern Ry.

From William H. Paine, New York:

Specifications for Iron Work of Suspended Structure of East River Bridge. 1878.

From Portugese Association of Civil Engineers, Lisbon:

Review of Public Works and Mines. January, 1878.

From L. W. Post, Jersey City, N. J.:

Specifications for Reservoir No. 3, Jersey City Water Works. 1878.

From H. G. Prout, Cairo, Egypt:

General Report on the Province of Kordofan, Lt. Col. H. G. Prout, Cairo. 1878.

From F. Rinecker, Wuerzburg, Germany:

Dass Gotthard-Unternehmen. Eine zusammenstellung der wichtigsten projecte in technischer und finanzieller beziehung. F. Rinecker, Munchen. 1878.

From the Royal United Service Institution, London:

Journal of the Institution, No. XCIV. 1878.

From H. Seymour, Jr., Albany, N. Y.:

Report of the State Engineer on the Canals of New York. 1877.

From William B. Sherman, New Bedford, Mass.:

Eighth Annual Report of the Acusbnet Water Board, New Bedford. December, 1877.

From T. E. Sickels, New York:

Report to Stockholders of Union Pacific Railroad. 1877.

From William Sooy Smith, Maywood, Ill.:

Specifications for masonry and for superstructure of the Glasgow Bridge. W. Sooy Smith. 1878.

From the Society of Engineers, London:

Transactions for 1877.

From Adjt-Gen. W. S. Stryker, Trenton, N. J.:

Record of Officers and Men of New Jersey in the Civil War, 1861-1865. 2 vols. Trenton. 1877.

From the Swedish Society of Engineers, Stockholm:

Record of the Society. 12th part. 1877.

From A. H. Thurston, Hoboken, New Jersey:

Application of electricity to regulation of railway traffic. F. L. Pope, Hartford. 1878.

From John D. Van Buren, New Brighton, N. Y.:

Annual Report of the State Engineer on the Canals. 1877.

From H. D. Whitcomb, Richmond, Va.:

Annual Report of the James River Improvement Committee to the City Council with report of the Engineer. 1878.

ANNOUNCEMENTS.

In the London "Building News and Engineering Journal" of July 5th, 1878, there is an extended abstract of the paper by Edward S. Philbrick, member of this Society, on the improvement of the South Boston Flats by the Harbor Commissioners of the State of Massachusetts, which was published in these Transactions as No. CLV, of Vol. VII, February, 1878.

An interesting manuscript description of the improvement of the Upper Seine and Yonne Rivers, by William Lucien Scaife, Civil Engineer, has been loaned to the library of the Society. Included in the monograph is a statement of the extent of inland navigation, both by canals and river improvements, in France, and an historical outline of its development. There are also very full descriptions of the different kinds of movable dams, with details of their construction and management. The methods of artificial floods and of continuous navigation are compared. Descriptions are given of the methods of transport in use, especially of towing by means of a sunken chain. Details of the cost of various improvements are given, and forms of the hydrometric and meteorological reports.

"London Engineering" of July 26th, 1878, reprints paper CL, Transactions of this Society (Vol. VI, October, 1877), "Description of Survey for determining the Slope of Water Surface in the Erie Canal," by William H. Searles.

"The London Iron" of July 27th, 1878, reprints paper CLVII, Transactions of this Society (Vol. VII, March, 1878), "Steam Engine Economy; a uniform basis for comparison," by Charles E. Emery,

In the "Annales des Ponts et Chaussees" for February, 1878, is printed a translation of paper CXXXIX, Transactions of this Society (Vol. VI, April, 1877), "The consumption and waste of water delivered by public works," by James H. Harlow.

The following reports and papers are at the Society rooms for distribution among such members as apply for them, sending at the

same time stamps for the prepayment of postage. It will be sufficient to note the numbers attached to each, which are in continuation of the list in Proceedings, Vol. III, page 78, July, 1877:

8th Report of the Improvement of the South Pass of the Mississippi River. Capt. M. R. Brown, Corps of Engineers, U. S. A. [29.]

9th Report of the Improvement of the South Pass of the Mississippi River. Capt. M. R. Brown, Corps of Engineers, U. S. A. [30.]

Report of Chief Engineer Board of Public Works of Jersey City, L. W. Post. [31.]

Report of the Committee of Engineers' Club of Philadelphia, on the Metric System of Weights and Measures. [32.]

Report of progress of work on the Cincinnati Southern Railway. [33.]

The strength of wrought-iron, as affected by its composition and by its reduction in rolling, A. L. Holley. [34.]

An investigation as to the mode and amount of attraction between large and small bodies in contact or at small distances, S. Whipple. [35.]

The Hayford process and apparatus for preserving timber, E. R. Andrews. [36.]

Report of the trial of the steam machinery of the United States Revenue Cutter "Gallatin." [37.]

If postal orders are made use of in transmitting money to the Treasurer or Secretary, care should always be taken to send at the same time the full name of the person to whose order it is drawn, with official title, if any such is given at the time of obtaining the order. This information is absolutely required to secure the payment of an order at the New York Post Office.

A photograph was taken of the members of the Society during their recent visit to Lowell on June 21st. Any person desiring a copy can obtain it by sending his address to Mr. James B. Francis, Lowell, Mass. Price $1.00.

Discordant Standards of Measurement.—A number of members of the Society desire to obtain for publication, statements of the various discordant standards of measure in use in the United States. It is known that in many cities the old standards are more or less at variance with the present, and that, quite frequently, confusion and annoyance are the result. A table, compiled from the information which is undoubtedly in the possession of members of the Society, would be both interesting and valuable. The request is, therefore, made, that any information which would be of assistance in the preparation of such a table be forwarded to the Secretary. The replies should state the equivalent of the measures referred to in U. S. standard feet or in meters, together with any additional notes which may be applicable. If provisional equivalents, afterwards proving incorrect, have been adopted, the value of these should also be stated.

Members who desire to secure complete sets of the Transactions of the Society are requested to send to the Secretary a list of the papers which are needed to fill up their sets. Some of the earlier papers are out of print. If orders are received for a sufficient number to warrant the expense, a reprint will be made.

Special attention is called to the code of rules for award of the Norman Medal, printed at the end of this number. Papers for competition must be submitted previous to September 6th, 1878. All members of the Society are invited to assist in securing the presentation of papers for this award.

Members of the Society who expect to visit Europe during the present year, are requested to inform the Secretary as soon as possible of that fact, and also of the time when they purpose leaving and the probable length of their stay abroad, together with their European address.

The following resolution was adopted at the Ninth Annual Convention of the Society, and ordered printed regularly in the Society publications:

Whereas, the metric system of weights and measures is now extensively used abroad; and whereas, it is desirable that the relation of the units of differing systems be made familiar to all, by comparison:

Resolved, That Members be requested, in papers hereafter presented to the Society, to write, in parenthesis, weights or dimensions by the metric system in connection with those of the system in general use.

The House of the Society is at 104 East Twentieth street, one door east from Fourth avenue, and near southwest corner of Gramercy Park. It is open from nine o'clock A. M. to five o'clock P. M. each business day except Saturday, when it is closed at three o'clock P. M.

The Library and Conversation Rooms will also, for the present, be open every *Thursday evening*, from 7½ to 10 P. M. Members are invited to avail themselves of the opportunities afforded on Thursday evenings both for consultation of books and periodicals, and for conversation.

LIST OF MEMBERS.

ADDITIONS.

MEMBERS.

		Date of Election
FIRMSTONE, FRANK	Glendon Iron Works, Easton, Pa.	Aug. 7th, 1878
NICHOLSON, GEORGE B.	Engineer's Office, Cin. Southern Railway, 70 West 3d Street, Cincinnati, Ohio.	May 1st, 1878
NICOLLS, WM. J.	Engineer Taylor Iron Co., 91 Liberty St., New York	June 5th, 1878

CHANGES AND CORRECTIONS.

MEMBERS.

BOGUE, VIRGIL G. ..... Care of Charles Watson, Lima, Peru.

CROES, J. JAMES R. ..... Eng. Additional Water Supply, Newark, N. J.

DAVIS, CHAS. E. L. B. ..... Capt. of Engineers, U. S. A., Box 900, Galveston, Texas.

FARLEY, JOHN E. ..... Asst. Eng. Tenn. River Improvement, Florence, Alabama.

McGEE, JOHN ..... Steubenville, Ohio.

PRINDLE, F. C. ..... Civil and Mechanical Engineer, 204 Walnut Place, Philadelphia, Pa.

VAN WINKLE, E. B. ..... Topographical Engineer Dept. Public Parks, 56th Street and Broadway, New York.

WELLMAN, D. W. ..... Asst. U. S. Eng. in charge Missouri River Survey, 1351 Washington Ave., St. Louis, Mo.

WISNER, GEORGE V. ..... 252 Park Street, Detroit, Mich.

American Society of Civil Engineers.

PROCEEDINGS.

Vol. IV, June, 1878.

MINUTES OF MEETINGS.

(Abstract of such as may be of general interest to members.)

OF THE SOCIETY.

August 7th, 1878.—The Society met at 8 p. m., William E. Worthen in the chair.

The ballot upon admission to membership was canvassed, and Frank Firmstone, of Easton, Pa., was declared elected as Member. The following resolution was offered by John W. Hill, and being duly seconded, was, in accordance with the rule, referred to the Board of Direction :—

Resolved, That a committee of five be appointed by the President to investigate and report upon the conditions calculated for maximum economy in the use of steam in steam engines.

The death on July 9th, 1878, of C. Ridgely Schott, member of the Society, was announced, and J. J. R. Croes and John Bogart were appointed a committee to prepare a memoir of the deceased.

August 21st, 1878.—The Society met at 8 p. m., John C. Campbell in the chair.

An addition to the paper by Theodore Cooper, entitled, "Observations on the Stresses Developed in Metallic Bars by Applied Forces," was read by the Secretary, and discussed by Messrs. Bogart, J. C. Campbell, Chanute, Emerson, Striedinger and Van Winkle.

REPORTS OF COMMITTEES
PRESENTED AT THE TENTH ANNUAL CONVENTION.

Report of the Committee on Tests of American Iron, Steel and other Metals.

Presented for the Committee by William Sooy Smith, Chairman.

Your Committee on Tests of American Iron, Steel and other Metals, offers for your consideration the following brief statement of its action during the interval that has elapsed since the date of its last report, and such remarks as naturally suggest themselves at this time touching the very interesting and important subject entrusted to its care.

During the month of April last, the chairman of your committee visited the national capitol and presented the claims of the United States Testing Board for the additional appropriations required for the continuance of its work. The inquiry was constantly made, "What has the Board already done, and what is it now doing with the money already appropriated?" Without a full and satisfactory answer to this inquiry, members of Congress were naturally unwilling to favor any further appropriation of money for the use of the Board. And in order that this information might reach Congress through the proper channel, a resolution was introduced in the House of Representatives, and passed, calling upon the President of the United States, to whom the Testing Board makes its reports, to inform Congress what had been done by this Board. It is understood that this information will soon be laid before Congress, when it will appear to the Congress and people of the United States, that a great deal of most valuable work has already been done by the Board, and that the investigation for which it was created, and which it has planned and undertaken, is of exceeding value to all classes of our people, and especially to the engineers, architects, mechanics, manufacturers and railroad men, not only of this country, but of the whole world. If the Board is only permitted and enabled to carry forward its examination of the steels produced by the Bessemer, Siemens-Martin, and other new processes, the knowledge obtained will be worth ten times the cost of the entire investigation which it has planned. The same may be said of nearly every branch of the enquiry marped out. To no men in he United States is this better known than to those to whom this report is addressed. Your committee doubt not that every engineer in the land desires to have our iron and steel tested in the exact sizes and shapes in which these metals are used in bridges and other structures. It is surely essential that we should know the right values of the constants which enter the formulas we employ in determining the strength of the various members which make up our structures. And is there one of us who can say what value we should assign to those which enter Gordon's or Rankine's formulas for calculating the strength of long columns to resist compression?

Several appropriations have been made—a board has been appointed and is at work—a testing machine is ready for the use of the Board, which is, or ought to be, the finest one ever constructed in this or any other country. A plan for the entire investigation has been devised which has met with the hearty approval of Engineers of this and other countries. The work is well begun—the necessity of its faithful prosecution and completion is apparent to all. If the government shrinks from the expenditure of the small sum necessary to carry forward this work, and the Board is permitted to pass out of existence, in accordance with the provision of an existing Act of Congress, when and how can the knowledge we so much need ever be obtained, and what shall we, as Engineers do without it, in the presence of the demands made upon us to construct works in the new materials offered for our use, and in shapes which we desire to use, but cannot, for want of correct knowledge as to their strength and behavior.

Unless Congress can be influenced to repeal the clause legislating the Board out of existence, and to appropriate the sum (say ten thousand dollars) necessary to enable the Board to go on with its work, from year to year, until it is done, the Board will cease to exist before another annual meeting of our Society. The testing machine which has been built for its use, will pass into the possession

of a government bureau, our profession and the country will be left to grope in the midst of the ignorance which exists, and suffer a lasting and poignant regret that a most deserving work should be permitted to fail, which has been so auspiciously begun.

The American Society of Civil Engineers, and many engineering schools, clubs and societies throughout the country, as well as colleges, mechanical Institutes, The American Institution of Mining Engineers, The Iron and Steel Association, and many distinguished engineers, architects and manufacturers have testified to the need of the investigation, and the thoroughness of its plan. The further action which your committee recommends, and it does so most earnestly, is the immediate use of every bit of personal influence which any member of our Society possesses to procure favorable action on the part of the committees on appropriations of the United States Senate and House of Representatives on the application made in behalf of the Board by your committee, for the appropriation of ten thousand dollars for the current expenses of the United States Testing Board during the next fiscal year.

Report of the Centennial Commission.

Presented by Theodore G. Ellis, Chairman.

The duties assigned to the Centennial Commission have all been completed, with the exception of preparing memoirs upon the various branches of Engineering exhibited at the Centennial Exposition. The preparation of these memoirs was assigned to sub-committees, only two of which have yet reported. The memoirs upon Light-house Engineering and upon Rivers and Harbors, have already been presented to the Society. It is hoped that the others are in preparation, and will soon be presented. Although it is a severe tax upon the time of the gentlemen to whom the duty has been assigned, it is a work for which they have been selected on account of their eminent fitness, and as it is a matter of great importance to the Society to retain a record of the interesting exhibit it presented, it is believed that these memoirs will be presented as soon as time can be spared to prepare them.

The commission still desires and hopes that a nearly complete set of these memoirs will be prepared, and it would be well to continue it until the several sub-committees have reported.

Report of the Committee on Permanent Quarters for the Society.

Presented by F. Collingwood, for the Committee.

The Committee reports that the lease of the house now occupied by the Society extends to May 1st, 1879. While there are certain inconveniences in the use of the present quarters, it will probably not be advisable to incur the expense of a removal, unless very decided advantages can be gained thereby. Should the Committee be continued, it will suggest to the Society any opportunity which may become available for permanent improvement.

Report of the Committee on Gauging of Streams.

Presented for the Committee by J. J. R. Croes, Chairman.

The Committee can only report that the hopes which they were led to entertain at the date of the last report, in November, have not been fulfilled; that no interest seems to have been taken by any persons in the matter, and that the two departments of New York City, which we had reason to think would give the results of observations, have failed entirely to respond. The Commissioner of Public Works had stated that the results of gaugings of the flow of the Croton river, continuous for the last two or three years would be published in the first quarterly report for 1878. That report has appeared, and there is nothing in it about it.

The Commissioners of Parks, who gave reason to believe that they would engage in the gauging of the streams in Westchester, in Wards 23 and 24 of New York, on finding that the necessary preparations for such gaugings would cost between two and three hundred dollars, laid the matter over indefinitely, and the Committee can only report that no progress has been made, much to their regret.

LIST OF NEW BOOKS ON

ENGINEERING AND TECHNOLOGY.

Alphabets, Book of. For Painters, Draughtsmen, Designers, &c. Including all standard styles and many new and popular ones Among others, German, French, Old English, &c. Jesse Haney. New York. *Am. News Co.* $0.50.

Astronomy. The main facts of popular —— and Mathematical Geometry. J. R. Langler. London 12mo, 2d ed *Simpkin.* 1s.

Bridge. The Illinois and St. Louis ——; by Prof. C. M. Woodward. Washington University S. Louis. This work is undertaken at request of Capt. Eads, and all questions of fact will be endorsed by him. Fully illustrated (Announcement)

——. The proposed Tower —. Observations to prove that a New Bridge east of London Bridge is unnecessary With Returns, showing the Traffic of London Bridge to be much Decreased. Peter W. Barlow. London. 8vo. *Spons.* 6d.

Canal and Culvert Tables. Louis D'A. Jackson. London. *W. H. Allen & Co.* (Announcement)

Carpentry and Joinery: Tredgold's and Tam's Atlas to. (Weale's Series.) London. 4to, 2d ed. *Crosby Lockwood.* 6s.

Casting and Founding. A practical Treatise, with descriptions of modern machinery employed. R. E. Spretson. London. 8vo, plates. *Spons.* (Announcement)

Chemistry. Elements of ——, Theoretical and Practical. Part 2. Inorganic Chemistry. W. A. Miller. London. 8vo. *Longmans.* 24s.

—— Handbook of Modern Chemistry. Inorganic and Organic. C. M. Tidy. London. 8vo. *Churchill.* 16s.

Civil Service Commission. Table of Rules and Regulations respecting Examinations for the Home Civil Service, the Army, the Civil Service of India, &c. 8vo. *British Government Publications.* 1s. 9d.

Cotton Manufacturers', Managers' and Spinners' New Pocket Guide, containing Examples of the various calculations connected with the Machinery of a Cotton Mill, with rules to find the speed of any shaft, drum, spindle, or roller connected with Machinery. John Moss. Manchester. 12mo. *Heywood.* 3s 6d.

Drawing. The parallel and meridian system of map drawing in connection with a ruler for making the parallels and meridians, whether straight or curved. W. V. Marshall. New York. 4to. *Barnes.* $0 20

Energy. The Conservation of ——. An elementary treatise on —, and its laws. Balfour Stewart. London. Post 8vo, new ed. *C. K. Paul* 5s.

Engineering Field Work. 2d ed. Revised, with additions and a supplementary volume on Waterworks. W Davis Haskoll. London. 8vo. *Crosby Lockwood.* 25s.

Examinations, Complete Guide to the Standard ——, consisting of twenty-four entire sets of paper on Arithmetic, with examples on other subjects. J. Heywood. London. 12mo (Announcement.)

Geology, Elementary. E. B. Andrews. Cincinnati. 12mo. *Van Antwerp, Bragg & Co.* $1.00.

Handbook to the Principal Professions, based on the most recent Regulations Concerning Admission to the Navy, Army, and Civil Services (Home and Indian); the Legal and Medical Professions; the Professions of a Civil Engineer, Architect, and Artist, and the Mercantile Marine. C. E. Pascoe. London. Post 8vo, *Low.* 3s. 6d.

Hydrostatics of the Cistern, Drain and Sewer. T. Morris. London. 12mo. *Simdkin.* 6d.

Kew. Report on the Progress and Condition of the Royal Gardens at Kew during the year 1877. Post 8vo. *British Gov't Publications.* 6d.

Lectures on the Labor Question. Thomas Brassey, M. P. 3d ed. London. 8vo. *Scribner & Welford.* New York. $3.00.

Mensuration and Measuring. T. Baker. New ed., rev. by E. Nugent. (Weale's Series.) London. 12mo. *Crosby Lockwood.* 1s 6d.

Microphone, The —— With notes on the Telephone and Phonograph. Alex. Watt. London. 32mo. *Houlston.* 6d.

Mint, The —— of the United States; a handbook of information as to how our coins are made. Wm. M. Runkle. Philadelphia. 8vo. *S. T Sowder.* $0.25.

Ornament —Designers' and Draughtsmen's Handbook of. With 112 Illustrations; explaining the various styles of Decoration. W. Gibbs. London. *Dean & Son.* 1s.

Painter's Manual. Jesse Haney. New York. *Am. News Co.* $0.50.

Paris Universal Exhibition of 1878. Victoria, Australia. Official Catalogue of Exhibits. Post 8vo London. *Burt.*

Philosophy — Deschanel's Natural. An Elementary Treatise. Trans. and extended by J. D. Everett. London. 8vo., illus. *Blackie & Son* 18s.

Physics ——. Questions and Problems in Elementary Physics, cont. numerous practical examples and exercises. C. L. Hotze. St. Louis. 12mo. *Central Pub. Co.* $0.75.

Punkahs—On the Working of, in India, as at present carried out by coolie labor, and the same operation affected by machinery. R. C. Parsons. London. 8vo. *Spons.* 1s.

Railroads: their Origin and Problems. Charles F. Adams, Jr. New York. 12mo. *Putnam.* $1.25.

Rainfall. Distribution of Rain over the British Isles during the year 1877, as observed at about 2 000 stations in Great Britain and Ireland. G. J. Symons. London. 8vo. *Stanford.* 5s.

Rocks —Classified and Described; A Treatise on Lithology. (Bernhard Van Cotta) An English edition by Philip Henry Lawrence, with English, German and French Synonyms. Revised by the Author. New ed. Post 8vo. *Longmans.* 14s.

Sewerage. Short History of the Wolverhampton; with a few hints on the Ventilation of House Drainage. G J C. Broom. London. 8vo. *Spons.* 1s 6d.

Technical Manuals, Cassell's. Illustrated throughout with Drawings and Working Diagrams, bound in cloth. London. *Cassel, Petter & Galpin.*

Bricklayers, Drawing for. 3s.
Building Construction. 2s.
Cabinet-Makers, Drawing for. 3s.
Carpenters and Joiners, Drawing for. 3s. 6d.
Gothic Stone Work. 3s.
Linear Drawing and Practical Geometry. 2s.
Linear Drawing and Projection. The two volumes in one. 3s. 6d.
Machinists and Engineers, Drawing for. 4s. 6d.
Metal-Plate Workers, Drawing for. 3s.
Model Drawing. 3s.
Orthographical and Isometrical Projection. 2s.
Practical Perspective. 3s.
Stonemasons, Drawing for. Cloth. 3s.
Applied Mechanics. Cloth. 2s.
Color. With colored plates. 2s 6d.
Systematic Drawing and Shading. 2s.

Timber and Log Book, Ready-Reckoner and Price Book. O. Byrne. New York. *Am. News Co.* $0.25.

Tramways Intelligence; A Short History, compiled from Official Sources, of the Principal Tramway and Omnibus Companies. With Useful Tables for Investors. Second year of issue. 8vo. *E. Wilson.* 1s. 6d.

Valve Gears. Slide ——. A new graphical method for analyzing the action of slide valves moved by eccentrics, link-motions and cut-off gears: offering easy means for designing valves and valve-gears, and for establishing the comparative merits of their various constructions. Hugo Bilgram. Philadelphia. *Claxton, Remsen & Haffelfinger.* $1.00.

Villages and Village Life, with Hints for their Improvement. Nathaniel Hillyer Egleston. Post 8vo. New York. *Harper & Brothers.* $1.75.

Water; Its Physical Properties, Sources, Distribution over the Earth, and Uses for Engineering and Sanitary Purposes. Prof. D. P. Ansted. London. *W. H. Allen & Co.* (Announcement.)

White Mountains — Stereoscopic Views; with descriptive text. Illus. by the Albertype process (with lens attachment). New York. 12mo. *Harroun & Bierstadt.* $3.00.

ADDITIONS TO

LIBRARY AND MUSEUM.

From American Iron and Steel Association, Philadelphia:
Annual Report of the Secretary, July 15, 1878.

From C. A. Angstrom, Stockholm, Sweden:
Expériences de force et de traction sur des tôles suédois produites par des procédés divers. Stockholm. 1878.

From the Argentine Scientific Society, Buenos Ayres:
Annals of the Society. Vol. III, 1877, and July, 1878.

From J. B. Bachelder, Washington:
Information as to preparation of the Engineer Maps of the Gettysburg battle-field. Washington. 1878.

From John Bogart, New York:
Original plates of three bridges erected near Philadelphia in 1813 by L. Wernwag.

From Boston Public Library:
Twenty-sixth Annual Report of Trustees. Boston. 1878.

From A. D. Briggs, Springfield, Mass.:
Report of Water Commissioners of Springfield. 1878.

From Civil Engineers' Club of the Northwest. L. P. Morehouse, Secretary, Chicago:
Proceedings of the Club. Vol. III. Chicago. 1878.

From Claxton, Remsen & Haffelfinger, Philadelphia:
Slide Valve Gears—a new practical method for analyzing the action of Slide Valves moved by Eccentrics, Link-motions and Cut-off Gears. Hugo Bilgram. Philadelphia. 1878.

From Eckley B. Coxe, Drifton, Pa.:
Address delivered before the Alumni Association of Lehigh University. E. B. Coxe. Philadelphia. 1878.

From Daniel Draper, New York:
Annual Report Meteorological Observatory. 1877. Daniel Draper. New York. 1878.

From James B. Eads, St. Louis:
Review of letter of Gen. A. A. Humphreys to Hon. E. W. Robertson. James B. Eads. Washington. 1878. (3 copies.)

From Albert Fink, New York;
Are the New York Railroads discriminating against the Commerce of New York City. Albert Fink. New York. 1878.

From B. M. Harrod, New Orleans:
Report of Board of Engineers on New Orleans Harbor. New Orleans. 1878.

From Rudolph Hering, Philadelphia:
Bearing Piles. R. Hering. Chicago. 1878.

From Clemens Herschel, Boston:
On the erosive and abrading Power of Water upon the sides and the bottom of Rivers and Canals. Clemens Herschel. Philadelphia. 1878. (Copies for distribution.)

From Julius E. Hilgard, Washington:
Report of the Superintendent United States Coast Survey, 1875. Hon. C. P. Patterson. Washington. 1878.

From Gen. A. A. Humphreys, Washington:
Instructions for observing the total Solar Eclipse of July 29th, 1878. Washington. 1878.
Ninth Report of Improvement of South Pass of Mississippi River. M. R. Brown. Washington. 1878. (Copies for distribution.)

From Institute of Civil Engineers, James Forrest, Secretary, London:
Abstract of Papers in foreign Transactions and Periodicals. Vol. III. Part 3. Session 1877–1878. London. 1878.
The Centrifugal Pump. Wm. C. Unwin. London. 1878.
Chemical and Physical Analysis of Phosphoric Steel. A. L. Holley, London. 1878.

Direct Acting or Non-Rotative Pumping Engines and Pumps. Henry Day. London. 1878.
The drainage, irrigation, and cultivation of the Albufera of Alcudia, Majorca; and application of the Common Reed as a material for paper. H. R. Waring. London. 1878.
On the main Drainage of Paris, and the utilization of its Sewage. Felix Target. London. 1878.
The Egremont Ferry Landing. Wm. Carson. London. 1878.
On the Flow of Water through Level Canals. James A. Longridge. London. 1878.
The Huevla Pier of the Rio Tinto Railway. Thomas Gibson. London. 1878.
Machine Tools. P. R. Allen. London. 1878.
Minutes of the Institution of Civil Engineers. With other selected and abstracted papers. Vol. LII. Part II. London. 1878.
Note on the Ventilation of Mount Cenis Tunnel. Wm. Pole. London. 1878.
Notes on Railway Appliances, at the Philadelphia Exhibition of 1876. Douglas Galton. London. 1878.
The Steam Navy. C. D. Fox, James Brand, H. M. Whilley, and C. A. Harrison London. 1878.
On the Strength of Flat Plates and Segmental Ends of Boilers and other Cylinders. Daniel K. Clark. London. 1878.

From the Iron and Steel Institute, Julien Deby, Secretary, London:

Journal of the Institute. No. 1. London. 1878.

From Charles Latimer, Cleveland:

Comparative Statement of Expenses in Engineer Department, Atlantic and Great Western Railway, April, 1877–78. Charles Latimer. Cleveland. 1878.

From Wm. H. Lotz, Chicago:

Reports. United States Coast Survey, 1865, '66, '67, '68, '69, '70, '71, '72, '73. Washington.
Theoretical-Practical Handbook of the manufacture of Pig Iron (German). B. Valerius. Freiberg. 1851.

From Charles Macdonald, New York:

Exposition des Ponts construits par Delaware Bridge Company. Paris Exhibition. Chas. Macdonald. New York. 1878.
Illustrated Album, Delaware Bridge Company. Charles Macdonald. New York. 1876.

From Wm. H. McFadden and Charles G. Darrach, Philadelphia:

Plans of Philadelphia Water Department. Wm. H. McFadden and Charles G. Darrach. Philadelphia. 1878.
Topographical Map of Philadelphia, showing Water Mains and Street Grades. Wm. H. McFadden and Charles G. Darrach.

From Wm. J. Nicolls, New York:

The Railway Builder. Wm. J. Nicolls. New York. 1878.

From Ernest Pontzen, Paris:

Ciments Portland. Notice sur les Chaux Eminemments Hydrauliques de Lafarge. MM. L. et E. Pavin de Lafarge. Paris. 1878.
Compagnie Française Ciment de Grenoble. Moreau, Porteret, Berethelot & Cie. Paris. 1878.
De l'emploi des Chaux et des Ciments Portlands. Lafarge. L. and E. Pavin de Lafarge. Paris. 1878.
Der Bau des Spitzberg-Tunnels auf der Pilsen-eisenstein-bahn. Aloise Stane und Carl Pascher. Berlin. 1878.
Excavateur pour grands Travaux de Terrassements, Ports, Canaux, Franchées, etc. A. Couvreux. Paris. 1878.
Exposition Universelle à Paris. Notice sur les Modeles, Cartes et Dessins relatifs aux travaux des Ponts et Chaussées reunis pas les soins du ministere des travaux publics. Paris. 1878.
Le Grand Ballon Captif á vapeur. Henry Gifford. Paris, 1878.
Technischer Bericht zum Projekte für die Marchfeld Bewasserung. J. von Podhasky. Vienna, 1878.
Usine de Frangey Quillot Frères fabricants à Frangey, par Lezinnes. Paris, 1878.

From Francis Rinecker, Würzburg:

Specifications of Pennsylvania Company, General form of Construction Contract.
Specifications of Pennsylvania Company, Grubbing, Clearing and Grading.
Specifications of Pennsylvania Company for Stone Masonry.

From Royal United Service Institution, B. Burgess, Secretary, London:

Journal of the Institution. Vol. XXII, 1878, No. XCV. London.
Journal of the Institution. Vol. XXII, 1878, No XCVI, London.
Appendix to Vol. XXI of the Journal of the Royal United Service Institution. London. 1878.

From Hon. Horatio Seymour, Jr., Albany:

Annual Report of State Engineer and Surveyor. H. Seymour, Jr. Albany. 1878.

From Société des Ingenieurs Civils, Paris:

Transactions of the Society. January and February, 1878. Paris.

From R. H. Thurston, Hoboken:

Results of a Series of Tests of Cold-Punched and Hot-pressed Nuts—a Report. R. H. Thurston. Philadelphia, 1878.
The Flow of Metals. David Townsend. Philadelphia, 1878.
Report of New Jersey State Commission appointed to devise a plan for the Encouragement of Manufactures of Ornamental and Textile Fabrics. Trenton, 1878.

From J. Nelson Tubbs, Rochester:

Annual Report of the Executive Board of Water Works of Rochester. Rochester, 1878.

From U. S. Light House Board, Washington:

New List of Buoys, Towers, Beacons, Stakes and other day marks in the Third Light House District. Corrected to July, 1878. Washington, 1878.

From George T. Walch, Madras, India:

Notes on some of the chief navigable rivers and canals in the United States and Canada. George T. Walch. Madras, 1878.

From William H. Wiley, New York:

Tunnelling. Explosive Compounds and Rock Drills. Henry S. Drinker. New York, 1878.

From other Sources:

Papers on subjects connected with the duties of the Corps of Royal Engineers, Vols. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10. London, 1847.
Opinion of the U. S. Circuit Court, District of Massachusetts, in the case of The Atlantic Giant Powder Company *vs.* George A. Goodyear, and the same *vs.* George W. Townsend. New York, 1878.
Record on motion for Interlocutory Injunc-

tion in the case of The Atlantic Giant Powder Company *vs.* George A. Goodyear. Boston, 1877.

Specification for the McAdamizing of the Flushing and North Hempstead Turnpike, in the Town of Flushing, Queens Co., N. Y., 1878.

Specifications and proposal for Asphaltum Pavements. Washington, 1878.

ANNOUNCEMENTS.

The Twenty-sixth Annual Meeting of the Society will be held Wednesday, November 6th, 1878, at 10 A. M.

In Vol LIII, Session 1877-8, part 3, of the abstract of papers in Foreign Transactions and Periodicals, published by the Institution of Civil Engineers, London, and edited by James Forrest, Secretary, there are abstracts of the following papers from Transactions of this Society :

Notes and experiments on the use and testing of Portland Cement, by W. W. Maclay (No. CLII, Vol. VI, December, 1877).

Igniting Blasts by means of Electricity; by Julius H. Striedinger (No. CLIII., Vol. VII, January, 1878).

The Improvement of the South Boston Flats; by Edward S. Philbrick (No. CLV, Vol. VII, February, 1878).

On a new method of detecting overstrain in Iron and other metals; by Robert H. Thurston (No. CLVI, Vol. VII, March, 1878).

The next regular meeting of the American Institute of Mining Engineers will be held at Lake George, October 15th, 1878.

Members who desire to secure complete sets of the Transactions of the Society are requested to send to the Secretary a list of the papers which are needed to fill up their sets. Some of the earlier papers are out of print. If orders are received for a sufficient number to warrant the expense, a reprint will be made.

Special attention is called to the code of rules for award of the Norman Medal, printed at the end of this number. Papers for competition must be submitted previous to September 6th, 1878. All members of the Society are invited to assist in securing the presentation of papers for this award.

All persons who desire a copy of the Bill now pending before Congress, to amend the Statutes in relation to Patents, should send their address to W. C. Hill, clerk of Senate Committee on Patents, Washington, D. C., who will immediately forward the same.

If postal orders are made use of in transmitting money to the Treasurer or Secretary, care should always be taken to send at the same time the full name of the person to whose order it is drawn, with official title, if any such is given at the time of obtaining the order. This information is absolutely required to secure the payment of an order at the New York Post Office.

A photograph was taken of the members of the Society during their recent visit to Lowell on June 21st. Any person desiring a copy can obtain it by sending his address to Mr. James B. Francis, Lowell, Mass. Price $1.00.

Discordant Standards of Measurement. —A number of members of the Society desire to obtain for publication, statements of the various discordant standards of measure in use in the United States. It is known that in many cities the old standards are more or less at variance with the present, and that, quite frequently, confusion and annoyance are the result. A table, compiled from the information which is undoubtedly in the possession of members of the Society, would be both interesting and valuable. The request is, therefore, made, that any information which would be of assistance in the preparation of such a table be forwarded to the Secretary. The replies should state the equivalent of the measures referred to in U. S. standard feet or in meters, together with any additional notes which may be applicable. If provisional equivalents, afterwards proving incorrect, have been adopted, the value of these should also be stated.

The following resolution was adopted at the Ninth Annual Convention of the Society, and ordered printed regularly in the Society publications:

Whereas, the metric system of weights and measures is now extensively used abroad; and whereas, it is desirable that the relation of the units of differing systems be made familiar to all, by comparison:

Resolved, That Members be requested, in papers hereafter presented to the Society, to

write, in parenthesis, weights or dimensions by the metric system in connection with those of the system in general use.

In reference to the foregoing resolution, a member of the Society, now in Europe, writes as follows:

I should like to draw the attention of members of the Society to a small instrument for the easy reduction of figures to the different standards. This is the sliding rule, invented by Gunter, in London, in 1624. Improved by Seth Partridge, in 1657, it came into use in the establishment of Boulton & Watt, at Soho, under the name of the Soho Rule. About thirty years ago, it was further improved by A. Mannheim, in France, by the addition of the *curseur*. Although the rules have various uses, they are of special value for the transformation of dimensions, weights, etc., from one to another standard; the rule making tables with their chances of misprints superfluous, only the reciprocal value of the units being required for its use.

THE HOUSE OF THE SOCIETY is at 104 East Twentieth street, one door east from Fourth avenue, and near southwest corner of Gramercy Park. It is open from nine o'clock A. M. to five o'clock P. M. each business day except Saturday, when it is closed at three o'clock P. M.

THE Library and Conversation Rooms will also, for the present, be open every *Thursday evening*, from 7½ to 10 P. M. Members are invited to avail themselves of the opportunities afforded on Thursday evenings both for consultation of books and periodicals, and for conversation.

LIST OF MEMBERS.

ADDITION.

MEMBER.

Date of Election.

CLARKE, ELIOT C .....Prin. As't Engineer in charge of Improved Sewerage, 74 Tremont St., Boston, Mass.....Sept. 4th, 1878

CHANGES AND CORRECTIONS.

MEMBERS.

ALDRICH, JAMES C.....North Scituate, R. I.

CHITTENDEN, S. H.....As't Eng. Elk River Shoals, Decatur, Alabama.

CORTHELL, E. L.....Res. Engineer, South Pass Jetties, 383 Friendship St., Providence, R. I.

HARLOW, JAMES H.....Prin. As't Eng. Davis Island Dam, Box 70, Pittsburgh, Pa.

HILL, JOHN W.....Mechanical Engineer, S. E. cor. Fifth and Walnut Sts., Cincinnati, Ohio.

WARFIELD, A. G., Jr.....Assistant State Engineer, San Francisco, Cal.

JUNIORS.

CLAY, GEORGE E.....7 West Forty-fifth Street, New York.

MERRIMAN, MANSFIELD...Prof. Civil and Mechanical Engineering, Lehigh University, Bethlehem, Pa.

WHINERY, SAMUEL.....As't Eng. U. S. Engineer Corps, Elk River Shoals, Decatur, Alabama.

RESIGNATION.

HAMILTON, SCHUYLER....Member .....Sept. 4th, 1878.

American Society of Civil Engineers.

PROCEEDINGS.

Vol. IV., July,* 1878.

MINUTES OF MEETINGS.

(Abstract of such as may be of general interest to members.)

OF THE SOCIETY.

SEPTEMBER 4TH, 1878.—The Society met at 8 P. M. O. Chanute in the chair.

The ballots upon admission to membership were canvassed, and declared George D. Ansley, of Montreal, Canada, and Eliot C. Clarke, of Boston, Mass., were declared elected members.

A paper by D. McN. Stauffer, entitled "Fall of the Western Arched Approach to South street Bridge, Philadelphia," was read by the Secretary and discussed by Messrs. Chanute, Emery, North, Schuyler, and Bogart.

SEPTEMBER 18TH, 1878.—The Society met at 8 P. M., M. N. Forney in the chair.

A letter from Thomas H. Johnson, describing Asphalt Pavements laid in Columbus, Ohio, and the results of traffic upon them, was read by the Secretary.

A statement as to the process of construction and method of laying

* The minutes of meetings are carried in this number up to November 6th, 1878. The fact that November proceedings are published in a number headed July is explained in the Annual Report of the Board of Direction. When the Board for the current year took office in November, 1877, the number of Transactions headed September, 1877, was the last that had been published. During the year as many numbers have been published as it was possible to do, and at the same time pay off the large accumulation of debt which was found to exist against the Society. The present number makes ten issues during the year, instead of twelve. As the Society is now entirely out of debt, it is purposed to make up the lacking numbers with the least possible delay.

various asphaltic pavements in the City of New York, including the Grahamite pavement on Fifth avenue, a road pavement in the Central Park, the Neuchatel rock pavement in Union square, and an asphaltic block pavement in Twenty-second street, was read by John Bogart.

A description of asphaltic pavements in Paris, and of a preserved wood block pavement laid in Boston, was given by Edward R. Andrews.

An asphaltic block pavement laid in Philadelphia was described by Edward P. North. A coal-tar pavement laid in Brooklyn, which has lasted a number of years, was described by Thomas P. Kinsley; and a pavement of coal-tar and stone, near Oxford, England, which has also stood many years, was referred to by David N. Melvin.

A pavement laid in Liverpool, of granite blocks, with gravel and pitch in the interstices, and covered to the depth of one inch with the same material, was described by George W. Dresser.

The subject of pavements was then generally discussed.

October 2d, 1878.—The Society met at 8 p. m., John C. Campbell in the chair.

The ballots for admission to membership were canvassed, and the following candidates were declared elected as members: Fred. P. Stearns, of South Framingham, Mass.; Marshall M. Tidd, of Lewiston, Me.; Frederick M. Wilbor, of Chatham, N. Y.

The ballot upon the following resolution was canvassed: "Resolved, That a committee of five be appointed by the President, to investigate and report upon conditions calculated for maximum economy in the use of steam in steam engines."

There were in favor of this resolution 38 votes, and against it 62 votes. The resolution was thereupon declared lost.

A report from the Board of Direction was read, as follows:

"The Board of Direction, having considered the resolutions and By-Laws relating to duties of officers, which have been referred to it, is of the opinion that, in the present condition of the Constitution and By-Laws, such amendments as have been proposed would only add to the existing confusion.

"It is of the opinion that the only method by which order can be brought out of the existing law is by a revision and codification of the Constitution and By-Laws."

A codification* of the present Constitution and By-Laws, not changing their provisions, but re-arranging and condensing the original provisions and adopted amendments, was then, in accordance with the above report, presented by J. J. R. Croes and seconded by John Bogart.

Amendments† to the Constitution and By-Laws were presented by J. J. R. Croes and seconded by F. Collingwood.

Amendments† to the Constitution were presented by George S. Morison and seconded by Charles Macdonald.

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* See page 95, (A.) † See page 105.

An amendment† to the Constitution was presented by Charles Macdonald and seconded by Edward P. North.

Diagrams showing the results of tests upon certain hydraulic cements and upon bricks were then presented by F. Collingwood, and a paper upon the subject was read by him.

October 16th, 1878.—The Society met at 8 p. m., Charles Macdonald in the chair.

A paper by R. Hering, upon the subject of "The Flow of Water, illustrated by Kutter's diagram for ascertaining the flow, with a description of the method of obtaining the mean velocity by inspection," was read by the author; and the diagram, drawn on a large scale with reference to small channels, with a table of co-ordinates, was presented. A blue photo-tracing of the diagram of Kutter, as exhibited at Philadelphia in 1876, was also presented by Mr. Hering.

The subject of the Flow of Water was discussed by Messrs. Worthen, Croes, Hering, and others.

November 6th, 1878.—The Twenty-Sixth Annual Meeting of the Society.—The Society met at 10 a. m. Vice-President W. Milnor Roberts in the chair. The following members were present:—

Messrs. Andrews, Baxter, L. F. Beckwith, Bogart, Boller, Brush, Collingwood, Cooper, Coryell, Croes, Joseph P. Davis, Dresser, Emery, Endicott, Charles H. Fisher, Bryant Godwin, Charles M. Harris, Kelley, Thomas P. Kinsley, Leavitt, Leverich, Lowthorp, Macdonald, Maurice, Charles L. McAlpine, Melvin, Morison, William H. Paine, Probasco, Raymond, Schuyler, Searles, Shinn, Joseph S. Smith, E. N. K. Talcott, John D. Van Buren, Van Winkle, Walling, Welch, William W. Wilson, Worthen, Yardley.

A letter* from the President, E. S. Chesbrough, was read.

The following tellers were appointed to canvass the ballots at this meeting:—G. W. Dresser, C. M. Harris, D. N. Melvin.

The Annual Report of the Board of Direction* was then presented, read by the Secretary, and on motion was accepted.

The Annual Report of the Treasurer* was presented, read and accepted.

The Report of the Finance Committee* was presented, read and accepted.

The Committee on Gauging of Streams presented a report* through J. J. R. Croes, Chairman, which was read, accepted, and the committee continued.

The Committee on Resistances of Railway Trains presented a report* through William P. Shinn, Chairman, and asked to be discharged. On motion the report was accepted and the committee discharged.

The Committee on Uniform Accounts and Returns of Railway

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* To be hereafter published. † See page 105.

Companies presented a report* through William P. Shinn, Chairman, which was accepted and the committee continued.

The Committee on Permanent Quarters for the Society presented a report* which was read, and on motion accepted and the committee continued.

The Centennial Commission presented a report* which was accepted and the commission was continued.

The Committee on Exhibit of American Engineering at Paris presented a report* through George S. Morison, Chairman, which was read. On motion the report and the memoir accompanying were accepted, and the memoir was referred to the Library Committee for printing in the Transactions of the Society.

On motion, it was also,

Resolved, That a vote of thanks be presented to the Committee on Exhibit of American Engineering at Paris.

The tellers then reported the result of the canvass of votes for officers of the Society, which was announced, and the following named members were declared elected officers of the Society for the ensuing year :—

President : W. Milnor Roberts.

Vice-Presidents : Albert Fink, James B. Francis.

Secretary and Librarian : John Bogart.

Treasurer : J. James R. Croes.

Directors : George S. Greene.
William H. Paine.
C. Vandervoort Smith.
Theodore G. Ellis.
Thomas C. Clarke.

The question of time and place for the Eleventh Annual Convention was then taken up. The Secretary presented a summary of the answers to the circular issued on this subject, as follows :

61	Members	suggested	St. Louis.
44	"	"	Cleveland.
11	"	"	San Francisco.
2	"	"	Baltimore.
2	"	"	Washington.

And each of the following places was suggested by one member : Buffalo, Chicago, Cincinnati, Montreal, New York, Richmond.

57	Members	suggested	June.
30	"	"	May.
5	"	"	April.
2	"	"	October.

And each of the following named months was suggested by one member : February, July, September.

The invitation presented at the Tenth Convention, that the Society should hold the next Convention at St. Louis, was repeated.

* To be hereafter published.

An invitation from members of the Society at Cleveland, that the Society should hold its next Convention at that city, was presented, as were also a letter of invitation from the Mayor of Cleveland and one from the Board of Trade of that city, tendering the use of its rooms for the meetings of the Convention.

After discussion, it was

Resolved, That a letter ballot be taken upon the question of the place of the Eleventh Annual Convention.

On motion, it was

Resolved, That no invitations to attend the Convention of the Society be extended to persons not members of the Society, except through the Board of Direction.

The result of the canvass of the ballots for membership was then announced, and the following named candidates were declared elected members :

William L. Baker, of Detroit, Mich. (elected Junior, January 6th, 1875); Frederick B. Howard, of Detroit, Mich. (elected Junior, March 3d, 1875); Wilmon W. C. Sites, of Jersey City, N. J.; Elnathan Sweet, Jr., of Albany, N. Y.

A recess was then (2 P. M.) taken for one hour.

On resuming the session, at 3 P. M., the report * of the Committee on Tests of American Iron and Steel, just received by telegraph from the Chairman, W. Sooy Smith, was presented, read, and accepted.

The Committee on Method of Nominating Officers presented a report * through J. J. R. Croes, Chairman, which was read, and on motion, accepted.

The proposed codification of the Constitution and By-Laws and the amendments offered were then considered.

After discussion, it was, on motion,

Resolved, That the codification of the present Constitution and By-Laws (as printed, page 95, (A.) be approved by this Annual Meeting, and recommended to the Society for adoption.

The proposed Amendments to the Constitution were then considered *seriatim*, and after discussion on each, the following action was taken :

Amendment to Article V. (B, page 105), recommended that it be not adopted.

Amendment to Article V. (C, page 105), recommended that it be not adopted.

Amendment to Article V. (D, page 105), recommended that it be not adopted.

Amendment to Article VI. (E, page 105), recommended that it be not adopted.

Amendment to Article VI. (F, page 106), recommended that it be not adopted.

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* To be hereafter published.

Amendment to Article VI. (G, page 106), recommended that it be not adopted.

Amendment to Article VII. (H, page 106), recommended that it be not adopted.

Amendment to Article IX. (I, page 106), recommended that it be not adopted.

Amendment to Article X. (J, page 106), recommended that it be not adopted.

Amendment to Article XVII. (K, page 106), recommended that it be adopted.

Amendment to Article XVIII. (L, page 107), recommended that it be adopted.

Amendment to Article XIX. (M, page 107), recommended that it be not adopted.

Amendment to Article XXIII. (N, page 108), recommended that it be adopted.

Amendment to Article XXXII. (O, page 108), recommended that it be adopted.

Amendment—a new Article (P, page 108), recommended that it be adopted.

The proposed amendments to the By-Laws were then considered, and after discussion on each, the following action was taken :

Amendment to Section 1 (R, page 108), recommended that it be adopted.

Amendment to Section 23 (S, page 109), recommended that it be adopted.

Amendment to Section 24, second clauso (T, page 109), recommended that it be not adopted.

An amendment to Section 24 of the By-Laws, which was embodied in the report of the Committee on the Method of Nominating Officers, was, on motion, referred back to the committee, and the committee continued.

The Annual Meeting adjourned at 6:45 P. M.

OF THE BOARD OF DIRECTION.

August 7th, 1878.—Applications for membership were considered. Appropriations were made and other financial business transacted.

September 4th, 1878.—Applications for membership were considered, The preparation of the Annual Report was directed.

October 2d, 1878.—Applications for membership were considered. Matters referred to the Board by the Society were discussed, and the preparation of a codification of the present provisions of the Constitution and By-Laws was directed. The report of the Committee on Nomi-

nations was received, and it was ordered that a letter ballot should be prepared and issued in accordance with the By-Laws. A report as to arrears of dues was presented by the Secretary, and special letters were directed to be sent to members in arrears.

October 31st, 1878.—Applications for membership were considered. appropriations made and financial business transacted. The Annual Report was considered in detail. The recovery of the railroad stock belonging to the Society, but not in its prossession for the past ten years, was reported by the Secretary.

November 5th, 1878.—The Annual Report was perfected. Financial business was transacted.

CONSTITUTION AND BY-LAWS OF THE SOCIETY.

[A.] Proposed Codification of the present Constitution and By-Laws.

(This codification does not change the present provisions of the Law of the Society, but is a re-arrangement and condensation of the original provisions and adopted amendments.)

Note. *This codification was prepared by the Board of Direction, and with a report* was presented and seconded at the meeting of the Society, October 2d,* 1878.

At the Annual Meeting, November 6th, 1878,† *this codification was approved and recommended to the Society for adoption. It, with the amendments printed below, will be submitted to letter ballot.*

CONSTITUTION.

Article I.—This Association shall be called the "American Society of Civil Engineers."

Article II.—Its objects shall be: The professional improvement of its members, the encouragement of social intercourse among men of practical science, the advancement of engineering in its several branches, and the establishment of a central point of reference and union for its members.

Article III.—Among the means to be employed for attaining these ends, shall be periodical meetings for the reading of professional papers and the discussion of scientific subjects; the foundation of a library, the collection of maps, drawings and models, and the publication of such parts of the proceedings as may be deemed expedient.

Article IV.—Civil, Military, Geological, Mining and Mechanical Engineers, Architects, and other persons who by profession are interested in the advancement of science, shall be eligible for admission in their appropriate class.

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* See page 90. † See page 93.

Article V.—The officers of the Society shall consist of a President, two Vice-Presidents, a Secretary, Treasurer, Librarian, and five Directors, who shall be elected by written ballot, by a majority of votes, at the Annual Meeting of the Society, and shall hold their offices until others are elected. Any vacancy occasioned by resignation or otherwise, may be filled at the next monthly meeting after notice of said vacancy.

Article VI.—The President, Vice-Presidents, Secretary, Treasurer and Directors shall constitute a Board of Direction, and shall be the Trustees of this Society, under the Act of the Legislature of April 12th, 1848, chapter 319, Laws of the State of New York.

Article VII.—The Board of Direction shall meet within one week after their election, and the first business in order shall be the appointment of a Standing Committee of three on Finance, and of a Standing Committee of three on Library.

Article VIII.—The President, and in his absence the Vice-Presidents in rotation, shall preside at all the meetings of the Society; and in case of their absence, a President pro tempore shall be appointed.

Article IX.—The Secretary shall keep an accurate record of all the transactions of the Society and of the Board of Direction, and shall issue all notices.

Article X.—The Treasurer shall have charge of the funds of the Society, receive all assessments and pay all bills and orders approved by the President or the Chairman of the Finance or Library Committees. The duties of the Secretary and Treasurer may be united in the same person, if the Society think proper. Moneys belonging to the Society, paid to any of its officers, shall, with a statement showing for what the payment was made, be promptly transmitted to the Treasurer, who shall receipt therefor.

The Treasurer shall deposit the moneys and invest the funds of the Society, in its name, by and with the advice of the Board of Direction; he shall sign all checks.

No indebtedness shall be incurred for the Society, except under such rules as prescribed by the Board of Direction.

No bill shall be paid for the Society until it has been certified by the person authorized to contract it, and audited by the Committee on Finance.

Article XI.—It shall be the duty of the Librarian to take charge of the library of the Society, and to see that all books are marked with the name of the Society, numbered, and recorded in a catalogue. In respect to the management of the library, he shall conform to such regulations as may be prescribed by the Society or by the Board of Direction.

Article XII.—The duties of the Board of Direction shall be: to have a general care of the affairs of the Society; to apply the funds in the treasury; to recommend the amount of assessments and appropriations for specific purposes, and to make a report on the affairs of the Society, embracing the report of the Treasurer, at the Annual Meeting.

Article XIII.—The Finance Committee shall have supervision of the accounts of the Society, shall examine all bills and demands, audit the accounts of the Treasurer, and certify to his annual report.

Article XIV.—The Library Committee shall have supervision of the rooms, printing and library of the Society, and shall apply to the purchase of books or other articles of permanent value to the Society, such sums as may be appropriated.

Article XV.—At any regular meeting of the Society, seven members shall constitute a quorum for the transaction of business. But the action of a less number at any monthly meeting, at which a quorum is not present, may be entered on the journal, provided such action does not affect the rights of the association, or any members thereof.

Article XVI.—The active members of the Society shall be divided into three classes, to be styled, respectively, Members, Associates and Juniors; and each person, when duly elected and qualified, shall receive a certificate of membership, indicative of the peculiar class which he represents. Associates and Juniors shall possess all the rights and privileges of Members, excepting the right of voting.

Article XVII.—To be eligible as a Member, the candidate must have been in the actual practice of his profession for at least seven years, and have been in charge of work or of operations in his particular branch of engineering or of science. A diploma from any collegiate institution in good standing, conferring the degree of C. E., shall be considered equivalent to two years' service. The candidate for Member must be a Civil, Military, Mining or Mechanical Engineer, who has been in active practice as such for seven years, or has graduated as Civil Engineer and been in practice for five years, and has had responsible charge of work as Chief, Resident or Superintending Engineer for at least one year; not as a skillful workman merely, but as one qualified to design as well as to direct public work.

To be eligible as an Associate, the candidate must be one whose connection with science or the arts qualifies him to concur with civil engineers in the advancement of professional knowledge. An Associate shall be a manager of a railroad, canal or other public work; a geologist, chemist or mathematician; a proprietor of a mine or metallurgical works; an architect or a manufacturer; or one who, from his scientific acquirements or practical experience, has attained eminence in his special pursuit, qualifying him to co-operate with engineers in the advancement of professional knowledge; but shall not himself be practicing as an engineer.

To be eligible as a Junior, the candidate must have been in the actual practice of his profession for at least two years, and shall be one who has had actual practice in some of the branches of civil, military, mining or mechanical engineering, for not less than two years; or if a graduate of a scientific or collegiate institution—for not less than one year.

Article XVIII.—All candidates for admission to the Society must file

statements by themselves, setting forth the grounds of their claim to be elected; be proposed by at least five members of the Society, to whom they must be personally known, and a notification of the same sent to each member whose place of address is on record. Each proposition, with the names of the proposers, must be posted in some conspicuous place in the rooms of the Society, for at least twenty-five days before being submitted to vote. All such papers and applications shall be laid before the Board of Direction, and be reported upon previous to action by the Society. Nominations and proposals for admission to the Society shall be endorsed by at least five members, who certify that they personally know the nominee or candidate, and that he is worthy of acceptance. The proposal of Member, Associate, or Junior shall contain a statement over the candidate's signature, of his age, residence, the nature and term of his professional service, and that he will conform to the requirements of membership, if elected. Honorary Members, Corresponding Members, and Fellows shall not be required to present themselves as candidates; those making the nominations shall state the grounds therefor, and certify that the nominee would accept if elected.

A proposal for transfer from one class to a higher shall be made by at least five Members, who state the age of the candidate, and the nature and term of his professional service since his admission to the Society. Such statement shall show a degree of qualification sufficient to render the proposed eligible to election in the class to which the transfer is asked. Upon approval of the Board of Direction, the candidate shall be balloted for, as provided for the election of members; and when the transfer is made, he shall not be required to pay an additional entrance fee.

Article XIX.—In elections for membership of either class, members shall vote by letter, or by ballot in the usual way, and the result shall be announced at the next regular meeting held after twenty-five days have elapsed from the time of mailing the notification. Five or more ballots cast in the negative shall exclude. Members notified, but not responding, shall be classed as having voted in the affirmative. In case of the non-election of any person balloted for, no notice shall be taken thereof in the minutes.

Article XX.—On being thus elected, the candidate must subscribe to the Constitution and By-Laws (in the terms set forth in Form A in the Appendix), and pay to the Treasurer of the Society such sum as may be determined upon, under the authority of Article XXII. of the Constitution, as the regular entrance fee and yearly assessment, before he can be entitled to receive his certificate of membership. If this be not done within six months from notification of the election, said election shall be considered void.

Article XXI.—Persons thus elected and duly qualified, who reside within fifty miles of the Post Office in the City of New York, shall be

deemed resident; and those who reside beyond this limit shall be deemed non-resident. The membership of any person shall begin on the day of his election.

Article XXII.—The amount of entrance fee to be paid, as well as the annual dues or assessments for the support of the Society, shall be determined from time to time, at some regular meeting of the Society, provided that notice of intended action thereon shall have been given at a previous regular meeting. No alteration in the amount of said fees or assessments shall apply to the fiscal year during which it is made, but shall take effect on and after the first Wednesday in November next succeeding the day of the date of said alteration. Members who become residents or non-residents by removal into or beyond the limits prescribed in Article XXI. shall be subject to assessments in the class in which they were on the day of the Annual Meeting, as may appear upon the records of the Society or by written notice to the Secretary.

Article XXIII.—Honorary members, not exceeding forty in number, having been nominated as required in Article XVIII., may be elected by a unanimous vote. An Honorary Member shall be one of acknowledged eminence in some branch of engineering, who has had not less than thirty years' practice.

Persons residing out of the United States may be elected Corresponding Members, in the same manner as hereinbefore provided for the choice of immediate members. A Corresponding Member shall be one, not a resident of the United States, eminent in a special branch of engineering, or able to supply valuable information relating thereto, who will communicate with the Society at least once a year. Corresponding and Honorary Members shall be subject to no fees or assessments. They may attend any meetings of the Society, but shall not be entitled to vote.

Article XXIV.—There shall be a fund, called the "Fellowship Fund," devoted exclusively to the publication of the papers read before the Society. Any persons, whether members or otherwise, if acceptable to the Society, may subscribe thereto. The subscribers to this fund shall be called "Fellows of the Society." A Fellow shall be an acceptable subscriber, who has signified to his proposers a desire to be nominated, and an intention, if elected, to become a member of this class.

Persons who are not members, and who become Fellows, shall be entitled to all the privileges of the Society, except the right to vote. Members who become Fellows, shall, in addition to all the rights they possess as members, be entitled to receive duplicate copies of all the publications of the Society.

Article XXV.—Whenever any person is elected, the Secretary shall immediately inform him of the same by letter (Form B in the Appendix), and the election of Honorary Members shall be likewise communicated to them by a letter suited to each particular case; but no person shall be

considered a Corresponding or Honorary Member unless he signify within six months his acceptance of membership.

Article XXVI.—Every person admitted to the Society shall be considered as belonging thereto and liable to the payment of all assessments, until he shall have signified to the Secretary his desire to withdraw; when, if his dues have been fully paid up, his name shall be erased from the list of members. Members in arrears for more than one year's annual dues shall not be allowed to vote until such dues are paid.

Article XXVII.—Any person admitted to the Society, who shall refuse to pay any assessment or other dues to the Society, or who shall neglect the same for the term of six months after due notice is issued (in the Form C in the Appendix), shall cease to be a member.

Article XXVIII.—Upon the written request of ten or more Members that, for cause therein set forth, a person belonging to the Society be expelled, the Board of Direction shall consider the matter, and if there is sufficient reason, shall advise the accused that his resignation will be accepted. He may, upon demand, receive a copy of the charges against him, and present a written defense. Two months after such advice was given, the Board of Direction shall finally consider the case, and if resignation has not been tendered, or a satisfactory defense made, will then notify the member that he will be expelled in one month, unless he elects to appeal from this decision. Appeals will be submitted to the Society by letter ballot. In case no appeal be made, the Board of Direction will expel the member, and notify him and the Society of the same, or of the action of the Society on appeal, and the above shall, in any event, be the only public announcement of the matter.

Article XXIX.—The permanent place for the transaction of the business of this Society shall be in the City of New York.

Article XXX.—The Annual Meeting for the election of officers and the hearing of the annual reports shall be held on the first Wednesday in November.

Article XXXI.—The annual contributions shall become due at the time of the Annual Meeting, and shall be payable in advance; and it shall be the duty of the Secretary to notify the amount of assessment or subscription due at the time of giving notice of such meeting.

Article XXXII.—Proposed amendments to this Constitution shall be first submitted to the Society and seconded, and then sent by letter to the several Members of the Society at least twenty-eight days previous to the Annual Meeting. Such amendments shall be in order for discussion at such Annual Meeting, and shall be voted upon by letter ballot, within sixty days after the date of said meeting. The vote shall be counted by the President and Secretary, and if two-thirds of the votes are in favor of said amendment, it shall be declared adopted, and the result announced at the next regular meeting of the Society thereafter.

BY-LAWS.

Section 1.—The regular meetings of the Society shall be held on the first Wednesday in each month. There shall be meetings of the Society held on the third Wednesday in each month for professional improvement, and the encouragement of social intercourse among men of practical science, at which papers shall be read and subjects discussed relating to the theory and practice of engineering, and no other business transacted. The Board of Direction may suspend meetings of the Society in the months of July and August.

A convention of the Society, for professional discussion and social intercourse, shall be held annually at such place as the Society may determine, and be presided over by a Chairman selected from among members not officers of the Society. During the Convention a regular meeting of the Society, to be presided over by the officers of the Society, may be held for the transaction of business.

The officers of the Society may give a reception at the Society's rooms, on the evenings of the second and fourth Wednesdays of each month between October and April, for the purpose of informal professional conversation and social intercourse. Regulations concerning refreshments and the invitation of guests may be made by a committee appointed for the purpose, but shall be without expense to the Society.

Sec. 2.—At the regular meetings of the Society, the following order shall be observed in the transaction of business, unless set aside for the time being by a vote of the members present:

1st. The record of last meeting to be read, approved and signed by the Chairman and Secretary.

2d. Candidates for membership to be balloted for.

3d. Communications received since the last regular meeting to be announced, and read if required.

4th. Communications from members present to be read.

5th. Communications from the Board of Direction to be brought forward.

6th. Reports of committees to be called for.

7th. Unfinished business to be taken up.

8th. New business to be proposed.

9th. Questions for debate to be discussed.

The same order shall be observed, as far as practicable, at the meetings of the Board of Direction.

Sec. 3.—All decisions of the Chair, on points of order, shall be conclusive, unless reversed on appeal to the meeting.

Sec. 4.—Every motion shall be first stated by the President, before debate or taking the question, and every motion shall be reduced to writing, if the President or any member desire it.

Sec. 5.—When a question is under debate, no motion shall be in order,

unless for the previous question ; to postpone indefinitely ; to postpone to a day certain ; to lay on the table ; to commit, to amend, or to adopt.

Sec. 6.—A motion to adjourn should always be in order, and shall be decided without debate.

Sec. 7.—If required by one-fifth of the whole number of members present, the ayes and nays upon any question shall be called, and entered upon the journal.

Sec. 8.—No motion for reconsideration shall be in order, unless one of the majority shall move such reconsideration. A motion for reconsideration, being put and lost, shall not be renewed, nor shall any subject or vote be a second time reconsidered without unanimous consent.

Sec. 9.—The Board of Direction may call meetings of the Society when they deem it expedient, and shall be bound to do so at the written request of seven members, stating the purpose of such meeting. Ten days notice shall be given to members of any special meeting ; the purpose thereof shall be stated in the notice, and no other business shall be taken up at that meeting.

Sec. 10.—The rooms of the Society shall be open from 9 A. M. to 4 P. M., every business day, unless otherwise determined by the Board of Direction.

Sec. 11.—Every member shall have the privilege of introducing visitors to the room while the Society is not in session, by writing their names and his own, in a book provided for that purpose.

Sec. 12.—A record of all donations to the Society, whether in money, books, maps, models or other articles of value, with the name of the donors, shall be entered by the Secretary in a book provided for that purpose, to be kept at the rooms of the Society.

Sec. 13.—The books, maps, and other property of the Society, shall only be removed from the rooms under such rules and regulations as shall be prescribed by the Committee on Library, and approved by the Board of Direction.

Sec. 14.—A book shall be kept by the Librarian, in which members may enter the title of any book, map or plan, which they may wish to have added to the library.

Sec. 15.—The records of the Society shall at all times be open to members, and such books of accounts shall be kept in its rooms as the Board of Direction may designate.

Sec. 16.—When a paper is presented to the Society, the Secretary shall at once examine it, and report thereon to the Committee on Library, with reference to this standard ; papers containing old matter, readily found elsewhere, those specially meant to advocate personal interests, those carelessly prepared or controverting established facts, and those purely speculative or foreign to the purposes of the Society, should be rejected. The committee shall then determine whether such paper may go before the Society. They can return it to the writer for correction

and emendation, and call to their aid one or more members of special experience relating to the subject treated, either to advise on the paper or to discuss it. Such papers as in the judgment of the committee should go before the Society shall promptly, upon their acceptance, be printed; others shall be recorded in books provided for the purpose. When, however, the Library Committee does not feel authorized to publish a paper, they may provide an abstract thereof, which, when approved by the author, may be published instead of the original paper.

Sec. 17.—The annual report of the Treasurer shall be certified to by at least two members of the Committee on Finance.

Sec. 18.—The Board of Direction shall determine the order of its stated and special meetings; provide for an executive committee to act in the absence of a quorum, or during the intervals between the meetings; prescribe regulations for balloting, and generally conduct the business affairs of the Society. The record of the proceedings of the Board of Direction made since the last regular meeting of the Society shall be read at each regular meeting.

Sec. 19.—A nomination or proposal shall be presented at the next regular meeting of the Board of Direction following its receipt; when it is thereby approved, and the applicant (if for admission as Member, Associate or Junior) classed with his consent, a day shall be fixed for the ballot to be canvassed, which shall be at a regular meeting of the Society, not less than twenty-five days thereafter.

Sec. 20.—When such day is fixed, the Secretary shall conspicuously post in the room of the Society the name and class of the nominee or applicant, his residence, occupation, and the names of his proposers; he shall mail to each member whose address is known a notice of the same, with a letter ballot in such form as shall be prescribed by the Board of Direction, and request the recipient to vote thereby or in person in the usual manner on the day fixed, when an open canvass of the votes cast shall be made, and the result announced.

Sec. 21.—The proposers of any rejected candidate may, within three months after such rejection, lay before the Board of Direction written evidence that an error was then made, and ask for a reconsideration of the proposal, which shall be granted on sufficient grounds, and if a ballot has been taken, another shall be ordered.

Sec. 22.—Persons who shall be elected members of this Society after six months of any fiscal year shall have expired, shall pay only one-half of the amount of dues for that fiscal year, otherwise required.

Sec. 23.—Special committees to report upon engineering subjects shall be authorized only by a majority of the votes cast by the Society, and in the following manner: Any resolution proposing such a committee shall be referred to the Board of Direction, which shall examine the same and report to the Society a concise statement of the argument for and against the appointment of such committee, which statement shall be printed

and issued to the Society with letter ballot; or, if the Board fails to report within one month, the letter ballot shall be issued without comment; or, the Society may vote by ballot at the Annual Meeting or in Annual Convention upon such resolution, within one month after it has been submitted to the Board of Direction.

Sec. 24.—1st. Votes for officers of the Society at the annual meeting in November may be sent by mail, inclosed in two sealed envelopes, the outer one of which shall be indorsed with the voter's signature, and all such votes shall be counted on the first ballot for officers.

2d. If it should appear that for any office a majority of the votes cast were not for one person, the meeting shall proceed to vote by ballot in the usual way for such officer, the choice of candidates being limited to the two persons not elected for whom the greatest number of votes had been previously cast for such office. In case three or more names have received an equal number of votes, the choice shall be made from among those names.

3d. At the Annual Convention a Nominating Committee of five members, not officers of the Society, shall be appointed by the Convention. This committee shall present to the Board of Direction, on or before the first day of October ensuing, the names of the persons selected by them as candidates for officers. Of these at least one Vice-President, three Directors, the Secretary and the Treasurer shall be resident members.

4th. The Board of Direction shall thereupon cause such list to be posted in the rooms of the Society, and shall issue, at least twenty days before the Annual Meeting, a letter ballot containing the names thus proposed.

5th. Any five members, not officers of the Society, may present to the Board of Direction, on or before October 1st. a list of names proposed by them for officers, which list or lists shall also be issued for ballot.

6th. No member of any Nominating Committee shall be presented by such committee as a candidate for office.

Sec. 25.—The President of the Society shall have the general supervision of the business and correspondence of the Society; he shall be an Honorary Member of all committees, but shall have no vote on such committees. In all cases where the By-Laws or resolutions of the Society or of the Board of Direction require specific duties to be performed by the President, the senior resident Vice-President present shall perform such duties in absence of the President, on receiving notice from the President to perform such duties.

Sec. 26.—Additions and amendments to these By-Laws shall be proposed in writing and seconded at a regular meeting, and then submitted to vote of the members by letter ballot, The vote shall be canvassed at the second regular meeting thereafter, and two-thirds of all the votes cast shall be necessary for the adoption of any such addition or amendment.

Amendments Proposed to the Constitution.

[The following amendments have been regularly offered and seconded. They were discussed at the annual meeting, November 6th, 1878, and action upon them taken as stated. They will be submitted to letter ballot.]

[*B.*] Amendments proposed to Article V.

At the Annual Meeting it was recommended that this be not adopted.

Article V.—The officers of the Society shall consist of a President, three Vice-Presidents, five Directors, a Secretary, a Treasurer and a Librarian, all of whom, except the Librarian, shall be members of at least five years standing.

The President, Vice-Presidents, and Directors shall constitute a Board of Direction, and shall be the Trustees of the Society under the provisions of chapter 319 of the Laws of the State of New York, passed April 12th, 1848.

[*C.*] Amendment proposed to Article V.

At the Annual Meeting it was recommended that this be not adopted.

Article V.—The officers of the Society shall be a President, three Vice-Presidents, five Directors, a Secretary, a Treasurer, and a Librarian. The President, Vice-Presidents and Directors shall be members of at least five years standing, and shall constitute a Board of Direction and be the Trustees of the Society, under the provisions of chapter 319 of the Laws of the State of New York, passed April 12th, 1848.

[*D.*] Amendment proposed to Article V.

At the Annual Meeting it was recommended that this be not adopted.

To amend Article V, so far as relates to the election of a Secretary, as follows:

Hereafter the Secretary shall be appointed by the Board of Direction, and hold his office during its pleasure. This amendment shall take effect on its passage and its provisions shall apply to the Secretary elected in November next.

[*E.*] Amendment proposed to Article VI.

At the Annual Meeting it was recommended that this be not adopted.

Article VI.—The members of the Board of Direction shall be elected by the Society by written ballot at the Annual Meeting of the Society, and shall hold their offices until others are elected.

Their term of office shall begin on the first of January succeeding the Annual Meeting, and shall continue one year, or until their successors are elected.

Any vacancies occurring during the year shall be filled by the Board of Direction.

The Secretary and Librarian and Treasurer shall be appointed by the vote of not less than six members of the Board of Direction and shall

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* See page 93.

hold office until removed by resignation or by a vote of not less than six members of the Board.

The duties of the Secretary and Librarian may be united in the same person if the Board so direct.

[*F.*] Amendment proposed to Article VI.

At the Annual Meeting it was recommended that this be not adopted.

Strike out the words, "The duties of Secretary and Librarian may be united in the same person if the Board so direct," and substitute for them the words, "The office of Librarian may be filled by an Associate or Junior, or its duties may be united in the same person with those of the Secretary."

[*G.*] Amendment proposed to Article VI.

At the Annual Meeting it was recommended that this be not adopted.

Strike out the same words as above, and substitute for them the words, "The offices of Secretary and Librarian may be filled by an Associate or Junior, and the duties may be performed by one and the same person."

[*H.*] Amendment proposed to Article VII.

At the Annual Meeting it was recommended that this be not adopted.

Article VII.—During the interval between the Annual Meeting and the first of January next ensuing, the President-elect shall appoint a Standing Committee of three on Finance, and of three on Library, from members of the Board for the ensuing year.

[*I.*] Amendment proposed to Article IX.

At the Annual Meeting it was recommended that this be not adopted.

Article IX.—The Secretary shall superintend the house of the Society, conduct the correspondence, edit the publications, issue all orders for supplies, and keep the books of account and records, all under the instructions of the Board of Direction and the Standing Committees. He shall receive such compensation for his services and such allowance for clerical aid as the Board of Direction may from time to time determine.

[*J.*] Amendment proposed to Article X.

At the Annual Meeting it was recommended that this be not adopted.

Aritcle X.—The Treasurer shall have charge of the funds of the Society, receive all moneys and pay all bills which have been certified by the Secretary and approved by the Finance Committee. He shall give bonds in the sum of five thousand dollars, for the faithful performance of his duties, which bonds shall be approved by the Board of Direction. He shall deposit the moneys and invest the funds of the Society in its name and by and with the advice of the Board of Direction. All disbursements shall be made by checks signed by him.

[*K.*] Amendment proposed to Article XVII.

At the Annual Meeting it was recommended that this be adopted.

Article XVII.—A Member shall be a Civil, Military, Mining or Mechanical Engineer, who has been in active practice as such for seven years, or has graduated as Civil Engineer and been in practice for five years, and has had responsible charge of work as Chief, Resident or

Superintending Engineer for at least one year; not as a skillful workman merely but as one qualified to design as well as to direct public work.

An Associate shall be a manager of a railroad, canal or other public work; a geologist, chemist or mathematician; a proprietor or manager of a mine or metallurgical works; an architect or a manufacturer, or one who, from his scientific acquirements or practical experience, has attained eminence in his special pursuit, qualifying him to co-operate with engineers in the advancement of professional knowledge; but shall not himself be practicing as an engineer.

A Junior shall be one who has had actual practice in some of the branches of civil, military, mining or mechanical engineering, for not less than two years; or if a graduate of a scientific or collegiate institution—for not less than one year.

A person to be eligible to any class of membership must not be less than twenty-one years of age.

[L.] Amendment proposed to Article XVIII.

At the Annual Meeting it was recommended that this be adopted:

Article XVIII.—Nominations and proposals for admission to the Society shall be indorsed by at least five Members, who certify that they personally know the nominee or candidate, and that he is worthy of acceptance. The proposal of Member, Associate or Junior shall contain a statement, over the candidate's signature, of his age, residence, the nature and term of his professional service, and that he will conform to the requirements of membership, if elected. Fellows shall not be required to present themselves as candidates; those making the nomination shall state the ground therefor, and certify that the nominee will accept if elected.

A proposal for transfer from one class to a higher shall be made by at least five Members, and shall state the age of the candidate, and the nature and term of his professional service since his admission to the Society. Such statement shall show a degree of qualification sufficient to render the proposed eligible to election in the class to which transfer is asked. Upon the approval of the Board of Direction, the candidate shall be balloted for, as provided in the election of members; and when the transfer is made, he shall be required to pay as an additional entrance fee the amount of the difference between the entrance fees of the two classes.

[M.] Amendment proposed to Article XIX.

At the Annual Meeting it was recommended that this be not adopted:

Article XIX.—Elections for active members shall be by letter ballot, and the result shall be announced at the next regular meeting held after twenty-five days have elapsed from the time of mailing the notification. Five or more ballots cast in the negative shall exclude.

In case of the non-election of any person balloted for, no publication thereof shall be made.

[N.] Amendment proposed to Article XXIII.

At the Annual Meeting it was recommended that this be adopted:

Article XXIII.—Honorary Members, not exceeding twenty in number in all, may be appointed by a unanimous vote of the Board of Direction and the Past Presidents of the Society. A person to be eligible as an Honorary Member shall be a gentleman of acknowledged eminence in some branch of engineering. Honorary Members shall be subject to no fees or assessments and shall not be entitled to vote.

[O.] Amendment proposed to Article XXXII.

At the Annual Meeting it was recommended that this be adopted:

Article XXXII.—Proposed amendments to this Constitution must be submitted in writing, signed by not less than five Members on or before the first Wednesday in October, and then sent by letter to the several Members of the Society, at least twenty-five days previous to the Annual Meeting. Such amendments shall be in order for discussion at such Annual Meeting and shall be voted upon by letter ballot, the vote to be counted at the first regular meeting in February. An affirmative vote of two-thirds of all ballots cast shall be necessary to secure the adoption of any amendment.

[P.] Amendment proposed ; a new article.

At the Annual Meeting it was recommended that this be adopted:

Article—(A new Article).—The Board of Direction may, for sufficient cause, excuse from payment of annual dues any member distinguished in his professional career, and who from ill-health, advanced age, or other good reason assigned, is unable to pay such dues ; and the Board may remit the whole or part of assessments in arrears, or accept in lieu thereof, desirable additions to the Library and Museum.

Amendments Proposed to the By-Laws.

[R.] Amendment to Section 1.

At the Annual Meeting it was recommended that this be adopted:

Section 1.—The regular meetings of the Society shall be held on the first Wednesday in each month. There shall be meetings of the Society held on the third Wednesday in each month, for professional improvement, and the encouragement of social intercourse among men of practical science, at which papers shall be read and subjects discussed relating to the theory and practice of engineering, and no other business transacted. The Board of Direction may suspend meetings of the Society in the months of July and August.

A Convention of the Society for professional discussion and social intercourse shall be held annually at such place as the Society may determine, and be presided over by a Chairman selected from among members not officers of the Society. During the Convention, a regular meeting of the Society, to be presided over by the officers of the Society, may be held for the transaction of business.

On the evening of the first day of the Convention, there shall be held

a meeting to which the public may be invited, and at which the President of the Society shall deliver an address giving a summary of engineering progress during the preceeding year.

[S.] Amendment to Section 23.

At the Annual Meeting it was recommended that this be adopted:

SECTION 23.—Special committees to report upon engineering subjects shall be authorized only by a majority of the votes cast by the Society, and in the following manner: Any resolution proposing such a committee shall be referred to the Board of Direction, which shall examine the same and report to the Society a concise statement of the argument for and against the appointment of such committee, which statement shall be printed and issued to the Society with letter ballot; or, if the Board fails to report within one month, the letter ballot shall be issued without comment.

[T.] Amendment to section 24, second clause.

At the Annual Meeting it was recommended that this be not adopted:

2d. The person having the greatest number of votes for the respective offices shall be declared elected. In case of a tie the decision shall be by ballot of the members present.

RESOLUTION SUBMITTED TO LETTER BALLOT.

The following resolution was presented at the meeting of the Society, held August 7th, 1878, and in accordance with the By-Laws was referred to the Board of Direction.

It was then submitted to letter ballot with the arguments for and against, as printed below, and the ballot being canvassed October 2d, 1878, the resolution was lost.

Resolved, That a committee of five be appointed by the President to investigate and report upon the conditions calculated for maximum economy in the use of steam in steam engines.

ARGUMENT FOR.

The causes which prevent the full utilization in an engine, of the steam generated by the fuel are various. The proportional effect of each of such causes and the best means of reducing such effect, are questions on which great diversity of opinion exists. These questions can best be solved by an analysis of the record of work done by existing machines when working under various conditions. Such an analysis can best be made by a committee of experts working under the auspices of the Society. A committee of this kind can obtain facts which could not be procured by individuals working separately, and can discuss and analyze the data collected in a manner not possible by independent observers. The aim of the resolution is the collection, in useful form, of information of value to all who are interested in steam engine economy, and is therefore in furtherance of the objects of the Society.

ARGUMENT AGAINST.

The determination of the relative effect produced by each of a multiplicity of causes working together cannot be reasoned out on general principles, but can only be made by several series of analytical experiments, in each of which care is taken to have one element variable while the others remain constant.

A committee of the kind proposed could not undertake such experiments, which would necessarily be expensive.

Published reports of the performance of different types of engines are so notoriously inexact and incomplete as to preclude the possibility of the deductions drawn from them being useful for a close analysis. The committee would be obliged, however, to base their conclusions on incomplete data, or else supplement them by theoretical reasoning. The report of a committee of this Society should be based on incontrovertible facts, and not be open to the criticism that where facts failed unsupported theory was called in to their aid.

For these reasons the appointment of the committee at this time seems unadvisable.

MEMOIRS OF DECEASED MEMBERS.

HENRY TYSON,* Member A. S. C. E.

DIED SEPTEMBER 1ST, 1877.

Henry Tyson was the son of Nathan and Martha Ellicott Tyson, and was born in the City of Baltimore on the 17th of October, 1820, and died in Baltimore on the 1st of September, 1877. He was descended from ancestors on both sides who were distinguished for vigorous intellects, and for their active exertions in favor of philanthropic measures, and who had been connected for several generations with the business and prosperity of the City of Baltimore.

He received his education partly at the collegiate department of the University of Maryland, in Baltimore, and afterward his studies were completed under the tuition of Samuel Smith, in Wilmington, Del.

In 1844 he was threatened with pulmonary disease, and for that reason spent the winter in traveling through the West Indies, and while there was attacked by the yellow fever. After his recovery, all traces of his former disease of the lungs entirely disappeared. In 1845 he made a voyage to Rio de Janeiro, and in 1846 another to the West Indies. During this last voyage his vessel was wrecked in mid-ocean, and the captain entirely disabled by a blow from a falling spar. The crew of the vessel became disorganized, and the vessel and all on board were in great danger of being lost, and probably would have been, had it not been for the presence of mind and ability of Mr. Tyson, who, with almost no one to help him, short of provisions, and without light at night, navigated the dismantled vessel into the harbor of St. Thomas, thus saving the cargo and the lives of all on board.

In 1847 he engaged in the flouring mill business in Baltimore, but his health again failing, he left the city, and resided for several years in the country, near Baltimore. In 1853 he was elected President of the Manteo & Perseverance Mining Company of North Carolina, and was actively engaged in engineering works in connection with the improvement of the mining properties, until he resigned the presidency. In 1856 he was appointed Master of Machinery of the Baltimore & Ohio Railroad. He occupied that position for about five years, and then, owing to some disagreement with the President of that company, his connection with the road was severed. During his administration, the

* Committee to prepare memoir, M. N. Forney, William R. Hutton, and John Bogart.

Board of Directors instructed him to prepare plans and specifications for freight engines for their road. Those used theretofore for the freight traffic had been chiefly eight-wheeled connected engines built by Winans and known as "Camel" engines. Mr. Tyson reported that these engines were very injurious to the track, and were very badly constructed, and recommended the use of ten-wheeled engines, that is, engines with six connected driving-wheels and a four-wheeled leading truck. Winans, instead of conforming to the ideas of Mr. Tyson and building ten-wheeled engines, undertook to show, in a series of letters published in the daily papers, that he (Tyson) was wrong. Public interest became very much excited, and the Board of Directors finally called upon Mr. Tyson for further information. He therefore addressed a note of inquiry to the subordinate officers in his department on the line of the road, asking for their opinion of the relative merits of the Camel and ten-wheeled engines. The replies unanimously condemned the Camel engine. These were then published in a pamphlet, and distributed through the length and breath of the land, and had the effect of entirely breaking up Mr. Winans' business, so that he ultimately sold off all his machinery and pulled down his shops.

The final solution, which time has worked, of the question which was then so warmly discussed, is that locomotives with eight wheels connected and without trucks are now not used in this country, but instead the Consolidation pattern is employed, with eight wheels connected, but with a truck having a single pair of wheels in front.

The system of sewerage adopted in 1860 for the City of Baltimore was devised by Mr. Tyson, but is still uncompleted. In 1861 he was elected President of the Baltimore City Passenger Railroad, which position he held for thirteen years. The plan for the improvement of Jones Falls (which, it may not be known, is a stream of water which flows through the centre of Baltimore in a very contracted channel, and is therefore subject to frequent overflow) which was adopted by the Mayor and City Council of Baltimore, was also the work of Mr. Tyson. He was appointed one of three commissioners to carry it out, but owing to a disagreement among them this was never done, and the plan was finally abandoned on account of its supposed excessive cost. In having his plan adopted and carried out, he was again opposed by Mr. Winans, who attempted in every way to show that the plan was inadequate or defective.

Mr. Tyson's plan for the introduction of the temporary water supply in Baltimore was the one finally adopted in 1872 by the City Council, at a saving of $200,000 over the plan previously agreed upon.

In 1873 he was elected Fourth Vice-President of the Erie Railway Company, with the duties of Superintendent of Machinery. He held this position only for a short time and then returned to Baltimore, where he was engaged in various matters pertaining to engineering. In 1875 he was appointed Receiver of the Chesapeake & Ohio Railroad, but re-

tired from that office in a few months. Soon after he was appointed Shipping Commissioner of the Port of Baltimore, and held that position at the time of his death.

He was a member of the American Society of Civil Engineers, although he never took an active part in its proceedings.

In social relations he was very popular, and owing to the versatility of his knowledge and wonderfully retentive memory, and, more than all, to his warm-hearted impulses, was much esteemed as a companion and friend. He had a wonderful power of exciting enthusiastic friendship and admiration among the subordinates in his employ. His conduct was uniformly courteous and respectful to all, from the highest to the lowest, and his salutation on entering his office in the morning to the half-witted man who swept it out was as respectful as it would have been to the president of the company.

Mr. Tyson was one of the few men who, during an active life, in which there was much experience calculated to embitter him, retained through all of it a love of doing good to others, especially if they were weak or helpless, and his chivalric devotion to the old and those in want or suffering, and his tenderness to little children, were marked characteristics.

He was independent almost to a fault, and incapable of anything like adulation for the purpose of securing the aid or good will of those whose influence or wealth would have helped him.

The most prominent traits of his character were not those which command wealth and power, but they caused all to respect him, and inspired in his friends and those much nearer to him the strongest and most ardent affection.

LIST OF NEW BOOKS ON

ENGINEERING AND TECHNOLOGY.

Architecture. The Old House Altered. George C. Mason. New York. 8vo, illus. *Putnams.* $2.50.

Bridges. Maximum Stress in framed Bridges. William Cain. New York. 16mo, illus. *Van Nostrand's Science Series, No.* 38. $0.50.

Chemistry. Elementary and Quantitative Analysis. Alexander Classen. With notes and add. by Edgar F. Smith. Philadelphia. Roy. 12mo, illus. *H. C. Lea.* $2.00.

——— A Dictionary of Chemistry and the Allied Branches of other Sciences. Henry Watts, assisted by eminent scientific and practical chemists. Five vols. 8vo, cloth. $50.25. Ditto, first supplement $11.25. Ditto, second supplement $13.50. *Longmans,* London. *Worthington,* New York.

——— Handbook of Modern Chemistry, Inorganic and Organic. For the Use of Students. Chas. Meymott Tidy. Philadelphia. 8vo. *Lindsay & Blakiston.* $5.00.

——— Manual of introductory chemical practice, for the use of students in colleges and normal and high schools. Geo. C. Caldwell and Abram A. Breneman. 2d ed rev. and corr. New York. 8vo. *Van Nostrand.* $1.50.

Coins. The Early Coins of America; and the Laws governing their Issue. Comprising also descriptions of the Washington Pieces, the Anglo-American Tokens, many pieces of unknown origin of the seventeenth and eighteenth centuries, and the first patterns of the U. S. Mint. Sylvester S. Crosby. Boston. 4to, illus., heliotype plates. *Estes & Lauriat.* $10.00.

College Book. Edited by Charles F. Richardson and Henry Alden Clark. Comprising historical and descriptive accounts, principally by professors or graduates, of twenty-four leading American Universities, Colleges, and the United States Military and Naval Academies, with excellent heliotype illustrations of one or more buildings connected with each of these institutions. New York. 8vo, illus. *Houghton, Osgood & Co.* (Announcement.)

Cyclopædia. Goodholmes' Domestic Cyclo

pædia. Todd S. Goodholme. New York. 8vo, illus. *Henry Holt & Co.* $5.00.

Dictionary, Brande & Cox. A Dictionary of Science, Literature and Art. W. T. Brande and G. W. Cox. New ed. imp. and enl. 3 vols. 8vo. *Longmans*, London. *Worthington*, New York. $22.00.

——— Ure's —— of Arts, Manufactures and Mines. Vol. IV. Supplementary to 7th ed. Robert Hunt. 8vo, illus. *Longmans*, London. *Worthington*, New York. $12.50.

——— Ure's —— 7th ed. Complete in 4 vols., including supplement. 8vo, illus. *Longmans*, London. *Worthington*, New York. $36.00.

Directory of the Engineers and Iron and Metal Trades and Colliery Proprietors throughout England, Scotland and Wales, and the principal towns in Ireland. 3d. ed. London. Roy. 8vo. *Kelley*. 30s.

Electric Lightning: A Practical Treatise. By Hippolyte Fontaine. Translated from the French by Paget Higgs, Assoc. Inst. C. E. With 48 engravings. *Spons*. London and New York. $3.00.

Encyclopædia of Civil Engineering, Cresy's. 1 vol. 8vo, illus. *Longmans*, London. *Worthington*, New York. $13.50.

Engineering. Pioneer ——. A Treatise on the Engineering Operations connected with the Settlement of Waste Lands in New Countries. By Edward Dobson, A. I. C. E. London. Crown 8vo, illus. and plates. *Crosby, Lockwood & Co.* 10s. 6s.

Geometry. Elementary Treatise on Coordinate Geometry. By Prof. DeVolson Wood. New York. *Wileys*. (Announcement.)

——— Theory of concentric spheres. By Symmes. Louisville. 8vo. *Bradley & Gilbert*. $0.50.

Geometrical Drawing, an elementary course. Containing Problems on the Right Line and Circle, Conic Sections and other Curves, the Projection, Section, and Intersection of Solids, the Development of Surfaces, and Isometric Perspective. George L. Vose. Boston 4to, plates. *Lee & Shepard*. $5.00.

Hygiene, Naval. An essay on the various influences affecting Human Health, and the various means of preventing Disease, etc. Joseph Wilson, M. D., Medical Director U. S. N. 2d ed. Philadelphia. 8vo, illus. *Lindsay & Blakiston*. (Announcement.)

Industries of Great Britain. Presenting a vivid, clear, and comprehensive Hist. of each of the Great Industries, described in all their various aspects. Fully illus. Vol. I. Extra. Crown 4to. *Cassell, Peller & Galpin*. London and New York. $3.00.

Landscape Art in England in 1878. A. Dawson. London. 8vo. *Deighton & Dunthoine*. 1s.

London. Catalogue of the Maps, Plans, and Views of London, collected by F. Crace, giving the title and size of each. London. 8vo. J. G. Crace. 21s.

Mechanics, Weisbach's. Vol. II., Part III.—Heat and Steam Engines. Julius Weisbach. Translated by Prof. A. J. Du Bois. With Notes on American Practice by R. H. Buel. New York. 8vo. *Wileys*. $6.00.

——— The Amateur Mechanics' Workshop. Plans and Concise Directions for Manipulating Wood and Metals, including Casting, Forging, Brazing, Soldering and Carpentry. By the author of "The Lathe and its Uses." Ills. 6th ed. London. 9vo. *Trubner*. 6s.

Mills and Millwork. A Treatise by Sir William Fairbairn. 4th ed. London. 8vo. *Longmans*. 25s.

Mineralogy. Dana's Manual of Mineralogy. New ed., almost entirely rewritten and brought up to date. New York. 12mo, cloth. *Wileys*. $2.00.

——— Brush, G. J. Manual of determinative mineralogy; with introd. on blow-pipe analysis (constituting the determinative part of Dana's mineralogy.) 3d. ed., tr. into the new system. George J. Brush. New York. 8vo, cloth. *Wileys*. $3.50.

Painters, Sculptors, Architects, Engravers, and their Works. A Handbook, with many illustrations and mongrams. By Clara Erskine Clement. 5th ed. re. and enl. Boston. Crown 8vo. *Houghton, Osgood & Co.* $3.25.

Paris: Its Parks and Gardens. Considered in relation to the wants of other cities, and of public and private gardens. 2d. ed. enl. and rev., with upwards of 350 ills. W. Robinson. New York. 8vo. *Macmillan & Co.* $7.50.

Political Register and Congressional Directory. A Statistical Record of the Federal Officers—Legislative, Executive, and Judicial—of the United States, 1776–1878. By Ben. Perley Poore, Clerk of the Senate Record. Boston. 1 vol. 8vo. *Houghton, Osgood & Co.* $6.00.

Precious Stones and Gems. E. W. Streeter. New York. 8vo. *Scribner & Welford*. $9.00.

Railways. Sketches, Historical and Descriptive. With practical information as to Fares and Rates, &c., and a Chapter on Railway Reform. By Joseph Parslow. London. Crown 8vo. *G. K. Paul & Co.* 6s.

Sanitary Examinations of Water, Air, and Food. By Cornelius B. Fox, M.D. Illus. 8vo. Philadelphia. *Lindsay & Blakeston*. (Announcement.)

Science. Half-hour Recreations in Popular Science. Second Series. Containing: Transmission of Sound by the Atmosphere, by John Tyndal; The Telephone, by Prof. F. J. Garbit, M. D.; The Phonograph, by Prof. F. J. Garbit, M.D., etc. Boston. Large 12mo. 1 vol. Estes & Lauriat. $2.50.

——— Handbooks for Students and General Readers in Science, Literature, Art and History; The Studio Arts, by Eliz. Winthrop Johnson: Astronomy, by R. S. Ball; Vertebrata, by A. McAlister, M. D. New York. 16mo. *Henry Holt & Co.* (Announcement.)

——— The American Science Series for High Schools and Colleges: Physics, by A. M. Mayer; Chemistry, by Sam. W. Johnson and William G. Mixter; Astronomy, by Simon Newcomb and Edward S. Holden; Geology, by Raphael Pumpelly; Botany, by C. E. Bessey; Zoology, by A. S. Packard, Jr.; The Human Body, by H. Newell Martin; Psychology, by Wm. James; Political Economy, by Francis A. Walker; Government, by Edwin L. Godkin. New York. *Henry Holt & Co.* (Announcement.)

Scientific Memoirs; being Experimental Contributions to a Knowledge of Radiant Energy. John William Draper. With por. New York. 8vo. *Harpers*. $3.00.

Sound: a series of simple, entertaining, and inexpensive experiments in the phenomena of sound, for the use of students of every age. Alfred M. Mayer. New York. 12 mo, illus. (Experimental Science Series for Beginners, No. 2.) *Appletons*. $1.00.

Steam Engine. A History of the Growth of the Steam Engine. Robert H. Thurston. New York. 12mo., illus. (Internat. Scientific Ser. V. 24.) *Appletons*. $2.50.

——— ——— Handbook of the ——— ———. John Bourne. 12 mo., illus. *Longmans*, London. *Worthington*, New York. $2.00.

——— ———. Recent improvements in the Steam Engine. With 124 wood-cuts. Foolscap, 8vo. John Bourne. *Longmans*, London. *Worthington*, New York. $2.50.

Tables and Memoranda for Engineers. J. C. Hurst. 3d ed., rev. London. 34mo. *Spons*. 1s.

University of Oxford: Examination of Women over Eighteen Years of Age. Examination Papers for the year 1878, with the list of Examiners and the Regulations. London. 8vo. *Parker*. 1s. 6d.

——— — ——— Local Examinations. Examination Papers for the year 1878, with list of Delegates and the Examiners, and the Regulations and Notices Prefixed. London. 8vo. *Parker*.

ANNOUNCEMENTS.

There were but nine Grand Prizes given to American Exhibitors at the Paris Exposition of this year. One of these was to the American Society of Civil Engineers for its Exhibit illustrating American Engineering.

The following resolution was adopted at the Ninth Annual Convention of the Society, and ordered printed regularly in the Society publications:

Whereas, the metric system of weights and measures is now extensively used abroad; and whereas, it is desirable that the relation of the units of differing systems be made familiar to all, by comparison:

Resolved, That Members be requested, in papers hereafter presented to the Society, to write, in parenthesis, weights or dimensions by the metric system, in connection with those of the system in general use.

THE HOUSE OF THE SOCIETY is at 104 East Twentieth street, one door east from Fourth avenue, and near southwest corner of Gramercy Park. It is open from nine o'clock A. M. to five o'clock P. M. each business day except Saturday, when it is closed at three o'clock P. M.

THE Library and Conversation Rooms will also, for the present, be open every *Thursday evening*, from 7½ to 10 P. M. Members are invited to avail themselves of the opportunities afforded on Thursday evenings both for consultation of books and periodicals and for conversation.

LIST OF MEMBERS.

ADDITION.

MEMBERS.

	Date of Election.
ANSLEY, GEORGE D.....City Surveyor, Montreal, Canada....	Sept. 4th, 1878
BAKER, WILLIAM L.....(Admitted as Junior, January 6th, 1875); Ass't Engineer Detroit Bridge and Iron Works, Detroit, Mich.....	Nov. 6th, 1878
HOWARD, FREDERICK B...(Admitted as Junior, March 3d, 1875); Civil Engineer, Abstract Building, Detroit, Mich.....	" "
SITES, WILMON W. C.....City Surveyor, Board of Public Works, Jersey City, N. J.....	" "
STEARNS, FRED. P.....Ass't Eng. Boston Water Works, South Framingham, Mass.....	Oct. 2d, 1878
TIDD, MARSHALL M.....Civil Engineer, 46 Court St., Boston, Mass.....	" "

RESIGNATION.

DA COSTA, JOHN C. (Member).....Oct. 10th, 1878.

American Society of Civil Engineers.

PROCEEDINGS.

Vol. IV., August,* 1878

THE ANNUAL REPORT OF THE BOARD OF DIRECTION FOR THE YEAR ENDING NOVEMBER 6TH, 1878. PRESENTED AND ACCEPTED NOVEMBER 6TH, 1878.

The Board of Direction, in compliance with Article XII of the Constitution, herewith presents a "Report on the affairs of the Society, embracing the Report of the Treasurer" for the term from November 7th, 1877, to November 6th, 1878.

On November 7th, 1877, the membership in the Society was:

Honorary Members, resident....	2	Non-resident....	4	Total.....		6
Corresponding Members.....	—	"	3	"		3
Members, resident..... ..	110	"	325	"	435	
Associates, "	4	"	12	"	16	
Juniors, "	9	"	46	"	55	506
Making.....	125		390			515
Fellows, 68—of whom 10 Members and 1 Honorary Member are included above, leaving.....						57
Total connected with the Society, November 7th, 1877						572

To-day the membership in the Society is:

Honorary Members, resident....	2	Non-resident....	4	Total.....		6
Corresponding Members.....	—	"	3	"		3
Members, resident.....	120	"	334	"	454	
Associates, "	4	"	13	"	17	
Juniors, "	8	"	49	"	57	528
Making.....	134		403			537
Fellows, 67—of whom 10 Members and 1 Honorary Member are included above, leaving.....						56
Total connected with the Society, November 6th, 1878.....						593

* These proceedings are carried up to November 6th, 1878. The explanation of this is given in the previous number.

The increase during the year has been :

Members admitted.....	25,	resigned, 5; died, 1;	increase....	19	
Associates admitted.....	1,		increase....	1	
Juniors admitted.....	5,	transferred to member, 3;	increase....	2	22
Fellows admitted.....	0,	died, 1;	decrease....		1
Total admitted	31 ; less resigned 5, transferred 3,				
died 2.....	10				
Making net increase	21				21

On November 7th, 1877, there were as stated in last report of Board, 8 proposals pending ; 30 proposals have been received during the year ; 24 candidates have been elected as members, of whom 3 were transferred from Juniors; 1 candidate has been elected as Associate and 5 candidates have been elected as Juniors ; 2 persons elected previous to November 7th, 1877, and 23 elected since that date, have qualified during the year as Members ; 1 Associate and 5 Juniors elected since that date have qualified as such during the year ; 1 candidate elected as Member during the year has not yet qualified, and there are six proposals now pending.

24 meetings of the Society were held during the year, one of which was the Tenth Annual Convention ; a meeting has been held on the first and third Wednesdays of each month, the ordinary recess during the summer not having been this year taken ; 19 meetings of the Board of Direction have been held during the year.

The Tenth Annual Convention was held in Boston, June 18th and 19th, 1878. This was followed by visits to various engineering works and points of interest in the City of Boston, and by excursions on the line of the water works, to places in the harbor, to Lowell, to Lawrence, to the White Mountains and over the White Mountain Railway, and by visits to Providence and Fall River.

Members of the Boston Society of Civil Engineers, of the Engineers' Club of St. Louis, of the Engineers' Club of the North West, of the Engineers' Club of Philadelphia, and other visiting engineers were present.

Full reports of the Convention have been published in Proceedings.

Reports made during the year were as follows :

By the Board of Direction : The Annual Report for the year. Also a report upon a ballot for membership; a report upon a ballot for adoption of a memorial; a report in reference to resolutions and By-Laws referred to it, embodying a proposed codification of the existing Constitution and By-Laws of the Society ; also the regular reports upon the applications for admission to the Society sent out with the letter ballots.

By the Finance Committee ; 1 Report.

By the Treasurer ; 2 Reports.

By the Board of Censors for the award of the Norman Medal ; 1 Report.

By the Centennial Commission of the Society ; 2 Reports.

By the Committee on the Exhibition at Paris ; 2 Reports.

By the Committee on Tests of American Iron and Steel ; 2 Reports.

By the Committee on Gauging of Streams ; 2 Reports.

By the Committee on Resistances of Railway Trains ; 1 Report.

By the Committee on Uniform Accounts and Returns of Railroad Companies ; 2 Reports.

By the Committee on Permanent Quarters for the Society ; 2 Reports.

By the Committee on Nomenclature and Classification of Masonry ; 1 Report.

By the Committee on the Metric System ; 1 Report.

By the Committee on time and place of Tenth Annual Convention ; 1 Report.
By the Committee on Nominations ; 1 Report.
By the Committee to Select Commissioner at Paris ; 1 Report.

The following papers and discussions have been published during the year ;

Relative Quantities of Materials in Bridges of different kinds, of various heights ; C. E. Emery. (No. CXLIX.)

Description of Survey for Determining the Slope of Water Surface in the Erie Canal ; W. H. Searles. (No. CL.)

Discussion of Connected Arc Marine Boilers ; J. F. Flagg.

Nomenclature of Building Stones and of Stone Masonry ; J. James R. Croes, William E. Merrill and Edgar B. Van Winkle. (No. CLI.)

Discussion on Levees as a System for Reclaiming Low Lands ; J. F. Flagg.

Notes and Experiments on the Use and Testing of Portland Cement : William W. Maclay. (No. CLII.)

On Igniting Blasts by Means of Electricity ; J. H. Striedinger. (No. CLIII.)

A Peculiar Case of Failure in a Water Main ; D. McN. Stauffer. (No. CLIV.)

Discussion on a Peculiar Case of Failure in a Water Main ; George S. Greene, jr., W. H. Paine. C. L. McAlpine, and Wm. J. McAlpine.

The Improvement of the South Boston Flats by the Harbor Commissioners of the State of Massachusetts ; E. S. Philbrick. (No. CLV.)

On a New Method of Detecting Overstrain in Iron and other Metals, and on its Application in the Investigation of the Causes of Accidents to Bridges and other Constructions ; R. H. Thurston. (No. CLVI.)

Steam Engine Economy, a uniform basis for comparison ; C. E. Emery. (No. CLVII.)

The Incline Plane Railroad at Madison. Its History and Operation. M. J. Becker, (No. CLVIII.)

On the Theoretical Resistance of Railroad Curves ; S, Whinery. (No. CLIX.)

Discussion on the Resistance of Railroad Curves ; O. Chanute, C. E. Emery, E. Yardley, Edward P. North, C. L. McAlpine, F. Collingwood and W. H. Paine.

On the Cause of the Maximum Velocity of Water Flowing in Open Channels being below the surface ; James B. Frances. (No. CLX.)

The Flow of Water in Pipes under Pressure ; Charles G. Darrach. (No. CLXI.)

Discussion on the Cause of the Maximum Velocity of Water Flowing in Open Channels being below the Surface, and also on the Flow of Water in Pipes under Pressure ; Theodore G. Ellis, C. E. Emery, C. Herschel, De Volson Wood and J. T. Fanning.

The South Pass Jetties ; Descriptive and Incidental Notes and Memoranda ; E. L. Corthell. (No. CLXII.)

Discussions on the South Pass Jetties ; Charles W. Howell, E. L. Corthell, C. Shaler Smith and J. Foster Flagg.

Papers and notes of discussion have been presented during the year, in addition to those published, as follows :

Brick Arches for Large Sewers ; R. Hering.
Discussion on Arches for Large Sewers ; W. Milnor Roberts.
Accident to Arch at Brooklyn ; F. Collingwood.
Discussion on the Relative Quantities of Material in Bridges ; W. H. Searles.
Accident to Cable at Brooklyn Bridge ; F. Collingwood.
Fall of Western Arched Approach to South Street Bridge, Philadelphia ; D. McN. Stauffer.
On Cements ; D. J. Whittemore.
On American Cements and Bricks ; F. Collingwood.
The Law of Tidal Currents in River Harbors ; J. H. Striedinger.
The Mediterranean Currents ; Charles H. Haswell.
On Wing Dams ; Theodore G. Ellis.
Brush Mattrass Dams ; J. Dutton Steele.
On the Means for Checking the Movement of the Falls of St. Anthony ; E. P. North.
The Dynagraph ; R. H. Buel.

Reminiscences and Experiences of Early Engineering Operations with especial reference to Steep Inclines ; W. Milnor Roberts.

On Incline Planes ; O. Chanute.

On Incline Planes ; W. H. Paine.

On the Nomenclature of Building Stones and of Stone Masonry ; J. Foster Flagg.

On the Nomenclature of Building Stones and of Stone Masonry ; J. J. R. Croes.

On a Newly Discovered Relation between the Tenacity of Metals and their Resistance to Torsion ; R. H. Thurston.

Observations on the Stresses Developed in Metallic Bars by Applied Forces ; T. Cooper.

On Stresses in the Eye Bar Head ; De Volson Wood.

Distribution of Rain-fall during the Great Storm of October 3d and 4th, 1869 ; James B. Francis.

On Gauging of Streams ; C. Herschel,

The Dangers threatening the Navigation of the Mississippi River, and the Reclamation of its alluvial Lands ; B. M. Harrod.

On Sewers ; E. S. Chesbrough.

On Steam Engine Economy ; E. D. Leavitt, Jr.

On Steam Engine Economy ; J. Foster Flagg.

On Railways Curves : J. Dutton Steele.

Graphic Method of Railroad Accounts : C. Latimer.

The Gravity of Water ; F. Collingwood.

The Flow of Water in Small Channels, after Ganguillet and Kutter, with Kutter's Diagram modified and graphical Tables with special reference to Sewer calculations : R. Hering.

The Proceedings contain, in addition to the reports mentioned :

Announcements in reference to discussions, ballots, illustrations of papers, donations to the library, times of meetings, members visiting Europe, the tenth annual Convention, reviews and extracts of papers of this Society published abroad, complete sets of Society Transactions, discordant standards of measurement, the Norman Medal, and papers for distribution.

Lists of Additions to the Library and Museum of the Society.

Lists of Additions to Membership and of Resignations and Deaths.

Lists of Changes and Corrections of Address of Members.

Letters of Invitation to Members of this Society from the Society of German Engineers.

Memoirs of deceased Members of the Society.

Memorial adopted on subject of extension of triangulations of the Coast Survey.

Minutes of the Meetings of the Society and of the Board of Direction and of the Convention at Boston.

Monthly lists of new books on Engineering and Technology.

Notes and memoranda in reference to the Exhibit of American Engineering at Paris, the Metric System of Weights and Measures, the Board to test Iron and Steel.

Notes as to the performance of the earlier engines on the Philadelphia and Reading Railroad.

Proposed Amendments to the Constitution and By-Laws.

Volume VI. of Transactions, and Volume III. of Proceedings closed with the December number, and Title Page and Index for each were issued with the January number.

Several years since, a handsome plate for Certificates of Membership in the Society was engraved, and a number of blanks on parchment, parchment paper, and plate paper were printed. An announcement was made, that on the payment of a sum stated, to cover the actual cost, a certificate would be forwarded to each member desiring it. Many were ordered and paid for but none were delivered, on account, as stated in the report of former boards, of an undecided question as to the time when the membership of an elected candidate begins.

During the past year, 105 Certificates of Membership have been finally

prepared, and all forwarded to the members who have ordered them, except a few which are waiting the signature of one of the former officers of the Society, who it is expected will soon be in New York, when they also will be completed and delivered.

The Board of Direction elected November 7th, 1877, held its first meeting for organization on Nov. 14th. The interval of a week allowed by the Constitution between the election and the first meeting of the Board was taken so that the non-resident members might have notice of and opportunity to attend this important meeting. It was then found that the last number of the Transactions that had been published was the one dated September, 1877. The next number was prepared directly and issued early in December; but, as will be seen, this was in the regular sequence headed as for October, thus really putting the heading of the number two months behind its actual issue. The Board has fully appreciated the desirability of regularity in publishing the Transactions; but, as will be explained in the statement as to finances, the necessity and great ulterior benefit to the Society of paying up its bills seemed so decided that it was considered best to make that the paramount work. Ten numbers have been published during the year. The remaining numbers, to bring the Transactions up to current dates, have been prepared in manuscript and can soon be published, as there are, at last, no financial difficulties to prevent.

The financial difficulties of the past year have been due to the fact that there were bills presented for liabilities incurred previous to the commencement of this year, and running back to 1874. It was found that the credit and good name of the Society were in danger, and it was determined to pay all these bills. The amount so paid, during the past Society year, of bills for liabilities incurred previous to the beginning of this year is $2,786 33.

The balance transferred from the previous year was also reduced by the payment, during the last month of that year, of bills amounting to over $1,000, which had been incurred during a period extending from December, 1872, to April, 1877.

The Board is happy to say that there are now no unpaid bills against the Society; that it transfers its control of affairs to its successors with no legacy of bills payable, and it congratulates the Society upon the fact, which it is believed exists for the first time in at least six years, that it is entirely out of debt.

It will be seen from the Report of the Treasurer that there are 117 members in arrears for dues, the amount of arrearages being $5,285. The greater portion of these members are believed to be willing to liquidate their indebtedness, but to have been unable to do so in consequence of the great depression in business. Toward such members who express a desire to retain their membership, and who evince that desire by payment in instalments, as opportunity offers, the Board feels that a lenient policy is the most just; but toward those who take no notice of requests for, at least, a reply to respectful communications asking for payment of their indebtedness, but one course can be pursued, and it is proposed to take measures to compel payment after the first of January next. It is suggested that members in arrears who may possess books and reports, copies of which are not in the Library, should dispose

of them to the Library at market rates, the amount of the same to be credited to their account.

The library has been increased during the year by the following additions :

Number of Books bound	190
" " unbound	200
" Pamphlets	378
" Maps	10
" Plans	32
" Photographs	46
" Drawings, Specifications, Models and Specimens	17

These do not include the magazines and papers contributed to the Society by publishers, or received in exchange for Transactions, as follows :—

American Architect and Building News	Weekly	Boston.
American Cyclopædia and Popular Science Monthly	Monthly	New York.
American Gas Light Journal	Semi-Monthly	"
Annales des Ponts et Chausèes	Quarterly	Paris.
Army and Navy Journal	Weekly	New York.
Builder	"	London.
Building and Engineering News	"	"
Commissioner of Patents Journal	Semi-Weekly	"
Deutsche Bauzeitung	"	Berlin.
Engineer	Weekly	London.
Engineering	"	"
Engineering and Mining Journal	"	New York.
Engineering News	"	Chicago.
Iron	"	London.
Iron Age	"	New York.
Journal American Iron and Steel Association	"	Philadelphia.
" of Franklin Institute	Monthly	"
" Society of Arts	Weekly	London.
Manufacturer and Builder	Monthly	New York.
Manufacturer and Iron World	Weekly	Pittsburg.
Monthly Record of Scientific Literature	Monthly	New York.
Polytechnic Review	Weekly	Philadelphia.
Railroad Gazette	"	New York.
Railway Age	"	Chicago.
Railway Review	"	"
Railway World	"	Philadelphia.
Scientific American	"	New York.
Telegraph Journal and Electric Review	Semi-Monthly	London.
Van Nostrand's Magazine	Monthly	New York.

The following are subscribed for :

Allgemeine Bibliographie für Deutschland	Weekly	Leipzig.
American Bookseller	Semi-Monthly	New York.
American Library Journal	Monthly	New York
Bibliographie de la France	Weekly	Paris.
Bookseller	Monthly	London.
Journal of Artillery and Military Engineering	"	Vienna.
Publishers' Weekly	Weekly	New York.

The Society has received during the year, in exchange for its "Transactions," official publications of the following associations, in some instances for preceding years :

Aeronautical Society of Great Britain	London.
American Institute of Architects	New York.
" Academy of Sciences	Washington.
" Institute of Mining Engineers	Easton, Pa.
Architecten und Ingenieur Verein zu Hannover	Hannover.
Argentine Scientific Society	Buenos Ayres.
Associacao des Engenueiros Civis Portuguezes	Lisbon.
Austrian Society Engineers and Architects	Vienna.
Boston Public Library	Boston.
British Patent Office	London.
Civil Engineers' Club of the Northwest	Chicago.
" " Philadelphia	Philadelphia.
" " St. Louis	St. Louis.
Die Administration der "Mittheilungen"	Vienna.
Engineer Department, U. S. A	Washington.
Essayons Club, Corps of Engineers, U. S. A	Willetts Point.
Imperial School	Moscow.
Institution of Civil Engineers	London.
" " of Ireland	Dublin.
" Engineers and Shipbuilders	Glasgow.
" Mechanical Engineers	London.
Iron and Steel Institute	"
North of England Institute of Mining and Mechanical Engineers	Newcastle-on-Tyne
Oesterreicher Ingenieur und Architecten Verein	Vienna.
Revue Générale des Chemins de fer	Paris.
Royal United Service Institution	London.
Russian Imperial Technic Society	St. Petersburg
Saxonian Society of Engineers and Architects	Dresden.
Smithsonian Institution	Washington.
Society of Arts	London.
" Engineers	"
Societe del Cuerpo de Ingenieros	Lima.
Société des Ingénieurs Civils	Paris.
Stevens Institute of Technology	Hoboken.
Swedish Society of Engineers	Stockholm.
U. S. Light House Board	Washington.
U. S. Military Academy	West Point.
U. S. Naval Observatory	Washington.
U. S. Ordnance Department	"
U. S. Patent Office	"

The present state of the Library is about as follows:

Books and Pamphlets	7,487
Manuscripts	95
Maps, Plans, Drawings, Charts, Photographs and Engravings	1,884
Models and Specimens	208

No paper has been submitted during the past year for competition for the Norman Medal.

The Committees existing at the beginning of the year are still continued, except those on Nomenclature and Classification of Masonry, and on the Metric System of Weights and Measures.

A Committee charged with the preparation of an Exhibition of American Engineering, at the Paris Exposition, was appointed during the year, and it is expected will report at this time.

A Committee was appointed at the business meeting during the Tenth

Annual Convention, to examine into the methods of election of officers adopted by various clubs and societies, and to report a By-Law embodying such features of the various plans as may seem best adapted for this society. This Committee will report at this time.

The lease of the present Society House, will expire on the first of May next. The Committee on permanent quarters for the Society will report on this subject at this meeting.

Amendments to the Constitution adopted during the year, have been as follows :

ARTICLE XIX.—For "two" insert "five" and for "thirty" insert "twenty-five." The article will then read :

All candidates for admission to the Society must file statements by themselves, setting forth the grounds of their claim to be elected; be proposed by at least five members of the Society, to whom they must be personally known, and a notification of the same sent to each member whose address is on record. Each proposition, with the names of the proposers, must be posted in some conspicuous place in the rooms of the Society for at least twenty-five days before being submitted to vote. All papers and applications shall be laid before the Board of Direction, and be reported upon previous to action by the Society.

ARTICLE XX.—In elections for membership of either class, members shall vote by letter or by ballot, in the usual way, and the result shall be announced at the next regular meeting held after thirty days have elapsed from the time of mailing the notification. Five or more ballots cast in the negative shall exclude. Members notified, but not responding, shall be classed as voting in the affirmative.

ARTICLE XXII. (To read.)—Persons thus elected and duly qualified, who reside within fifty miles of the Post Office in the City of New York, shall be deemed resident; and those who reside beyond this limit shall be deemed non-resident. The membership of any person shall begin on the day of his election.

ARTICLE.——(A new Article.)—Members in arrears for more than one year's annual dues shall not be allowed to vote until such dues are paid.

ARTICLE.——(A new Article.)—Upon the written request of ten or more members, that for cause therein set forth, a person belonging to the Society be expelled, the Board of Direction shall consider the matter, and if there is sufficient reason shall advise the accused that his resignation will be accepted. He may, upon demand, receive a copy of the charge against him, and present a written defense. Two months after such advice was given, the Board of Direction shall finally consider the case, and if resignation has not been tendered or a satisfactory defence made, will then notify the member that he will be expelled in one month, unless he elects to appeal from this decision. Appeals will be submitted to the Society by letter ballot. In case no appeal be made, the Board of Direction will expel the member and notify him and the Society of the same, or of the action of the Society on appeal, and the above shall in any event, be the only public announcement of the matter.

Amendments to the By-Laws adopted during the year have been as follows:

(A new Section.)—In all cases where the By-Laws or resolutions of the Society or of the Board of Direction require specific duties to be performed by the President, the senior resident Vice-President present shall perform such duties in absence of the President, on receiving notice from the President to perform such duties.

SECTION 26.—Additions and amendments to these By-Laws shall be proposed in writing and seconded at a regular meeting, and then submitted to vote of the members by letter ballot. The vote shall be canvassed at the second regular meeting thereafter, and two-thirds of all the votes cast shall be necessary for the adoption of any such addition or amendment.

The following clause was stricken out from section 23.

[The term Junior is to be understood as not referring to the age of the person, but to his

classification in the Society for the time being. He is Junior to Members in the sense that his professional experience has had a more limited scope than theirs, while he is eligible to become a Member, which an Associate is not,]

The Board, as was reported at the last meeting of the Society, has caused a codification to be made of the existing provisions of the Constitution and By-Laws.

Amendments have been offered, which are to be debated by the Society to-day.

The Secretary has, under direction of the Board, taken active measures to recover the value of a certificate for five shares of the stock of the New York Central Railroad Company, which certificate was lost, some ten years ago, by the former Treasurer of the Society. These measures have finally been successful, and the Board takes pleasure in stating that the value of the original shares, and the accumulated dividends, has been recovered. The amount placed in the treasury of the Society from this source, after paying all expenses, is, at par, $1,475.79.

Deaths of members during the year have been:

John F. Tracy, elected, as fellow, January 20th, 1873, who died February 13th, 1878, and a memoir of whom has been published.

C. Ridgely Schott, elected, as Member, April 1st, 1874, who died July 9th, 1878, of whom a memoir is in preparation.

Although not a member of the Society, Mr. Benjamin H. Latrobe was so prominent in our profession that the Board takes this occasion to announce his death, which occurred at Baltimore on the 19th of October, 1878, in the seventy-first year of his life. Mr. Latrobe was one of the pioneers of the engineering profession in this country. He took a most prominent part in the construction of the great railroad system from its infancy to its present full development. His bold design of ascending the Allegheny Mountains with steep grades, which he afterward carried out so successfully, received, as it merited, the admiration of engineers, and established for Mr. Latrobe a reputation as one of the foremost engineers of his time throughout the civilized world, which he has sustained by his works, and his personal character, to the end of his useful life.

Respectfully submitted.

JOHN BOGART,
Secretary,

REPORT OF THE TREASURER

For the Year ending November 6th, 1878.

Presented and Accepted at the Twenty-sixth Annual Meeting.

Receipts.

Balance on hand November 7th, 1877		$634 67
Entrance fees		775 00
Current dues—from 88 Resident Members	$2,162 50	
Do. from 270 Non-resident Members	3,957 50	
Do. from 5 Resident Juniors	75 00	
Do. from 44 Non-resident Juniors	139 88	
Do. from 3 Resident Associates	45 00	
Do. from 7 Non-resident Associates	65 00	
		6,754 88
Past dues—from 6 Resident Members	$175 00	
Do. from 18 Non resident Members	375 00	
		550 00
Dues for year beginning Nov. 6th, 1878:		
From 13 Resident Members	$325 00	
From 95 Non-resident Members	1,416 55	
From 14 Non-resident Juniors	140 00	
From 2 Non-resident Associates	20 00	
		1,901 55
Sales of Publications		283 21
Certificates of Membership		36 75
Miscellaneous		33 75
Proceeds of 5-20 Bond—Fellowship Fund—called in	$527 96	
Interest on Fellowship Fund Bonds	560 00	
Interest on Savings Bank Deposit	63 22	
Interest on Norman Medal Fund	70 00	
Accumulated Dividends on recovered Railroad Stock	975 79	
		2,196 97
		$13,166 78

DISBURSEMENTS.

Rent			$1,600 00
Janitor, House Supplies, Fuel, Furniture, Water and Gas			897 21
Library			119 82
Publications			1,943 70
Insurance			34 23
Postage			337 94
Salaries			3,000 00
Stationery and Printing			492 36
Norman Medal and Book Prize			128 15
Annual Meeting and Convention			300 71
Certificates of Membership			49 80
Other expenditures			128 80
Publications previous to Nov. 7th, 1877		$1,516 50	
Rent do. do.		400 00	
Salaries do. do.		58 33	
Legal services do. do.		160 88	
Miscellaneous bills previous to Nov. 7th, 1877		650 62	
			2,786 33
			$11,819 05
Transferred to Investment Account: See Statement herewith		$598 22	
Balance on hand		749 51	
			1,347 73
			$13,166 78

The funds of the Society are invested as follows, par values being stated:

Fellowship Fund:		
8 Bonds Jersey City Water Loan	$8,000 00	
Deposit in Seamen's Bank for Savings	886 12	
		$8,886 12
Norman Medal Fund:		
1 Certificate Croton Aqueduct Stock, New York City		1,000 00
General Investment:		
10 Shares New York Central and Hudson River R.R. Stock	1,000 00	
1 Consolidated Certificate New York Central and Hudson River R.R. Stock	35 00	
		1,035 00

There is due to the Society from its members for arrears of dues the sum of $5,285 00, distributed as follows:

46	Members	owe for	1 year	$780 00
19	do.	do.	2 do.	610 00
22	do.	do.	3 do.	1050 00
8	do.	do.	4 do.	540 00
9	do.	do.	5 do.	775 00
11	do.	do.	6 do.	1330 00
2	do.	do.	7 do.	200 00
117			Members owe	$5285 00

J. J. R. CROES,
Treasurer.

REPORTS OF COMMITTEES.

Report of the Committee on Finance.

Presented and Accepted Nov. 6th, 1878.

The Committee on Finance would respectfully present the following report for the year ending November 6th 1878:

The balance on hand, reported November 6th, 1877, was	$634 67
Outstanding indebtedness	1,810 58
Leaving a balance of indebtedness of	1,175 91
The receipts for the present fiscal year, as reported by the Treasurer, are	12,532 11
The expenditures have been	11,819 05

including the indebtedness left over from last year.

The committee would respectfully refer to the Secretary's and Treasurer's reports for the items of the foregoing summary. and would remark that the systematic arrangement of all of the accounts, not only with each individual debtor and creditor, but also with each appropriation fund, has been carried out in so thorough and practical a manner as to greatly lessen the labors of your committee.

Notwithstanding the efforts of the previous committee, we found there were still old outstanding bills and unsettled accounts.

The calling for receipts in full by our Treasurer has, we trust, brought in all such accounts, the number and amounts of which have been a matter of surprise and a severe drain upon our treasury.

The total amount of such bills paid during this year has been $2,786.33, to which we might properly add the amount of more than $1,020 presented near the close of last year, all of which has been withdrawn from the available funds of this year.

Your committee has brought this matter to the attention of the Board of Direction, which has taken action in appropriating funds and ordering these bills paid, which action now places our Society entirely free from debt.

Report of Committee on Tests of American Iron, Steel, and other Metals.

Presented for the Committee by William Sooy Smith, Chairman.

The Committee submits as a report the fact that the Board to Test American Iron and Steel is legislated out of existence just as its work is fairly begun.

Report of the Committee on Gauging of Streams.

Presented for the Committee by J. J. R. Croes, Chairman.

The Committee on Gauging of Streams respectfully reports that during the past summer some measurements have been taken of the minimum flow of the Passaic River, and some of its branches in New Jersey, the results of which they hope soon to be able to lay before the Society. The officers of the Geological Survey of New Jersey have expressed great interest in the efforts of the Committee, and anticipate the establisment, at an early day, of systematic measurements of the streams in portions of that State.

The Committee desires to call attention to the very interesting report of General Theodore G. Ellis on the measurements of the flow of the Connecticut River, made under the direction of the United States Engineers for several years, which report has recently been published by the War Department.

The system of measurement, and the results obtained, are therein fully detailed, and will be of great benefit to observers desiring to establish similar systems of gauging.

Report of Committee on Permanent Quarters for the Society.

Presented for the Committee by John Bogart, Chairman.

The Committee on Permanent Quarters for the Society begs to report that as the lease of the present Society House expires on the 1st of May next it will be necessary to determine whether it is best to renew it.

It will be inexpedient to move the Society effects unless there are strong reasons of economy or convenience for doing so. But the rent paid for this house is quite large, and it would be very desirable, if possible, for the Society to be properly accommodated at a lower rental. It is therefore suggested that the Board of Direction should ascertain whether a reduction of rental can be obtained—should ascertain whether other convenient quarters can be found at a rental sufficiently less to warrant removal, and should determine the question upon the combined considerations of economy and convenience.

The Committee have kept in view the general desire of the Society to secure, at the earliest practical period a suitable building of their own, or one of which a permanent lease might be advisable ; but it is well known that this is not immediately attainable.

Letter from the President of the Society,

Presented at the Twenty-sixth Annual Meeting, November 6th, 1878.

Chicago, Nov. 2d, 1878.

To the Members of the American Society of Civil Engineers:

Gentlemen,—On reaching the close of the term of office with which I feel the Society has greatly honored me, a custom that should not lightly be disregarded demands some statement from me, relative to the progress, condition, and prospects of the Society in particular, and of our profession in general.

I have to acknowledge, however, that the distance of my home from the central office, and the restraining circumstances, both private and official, in which I have been, and still am, placed here have prevented me from attending a single meeting of the Society during the year. While this has been a source of great regret, it has also been to me very gratifying to know that the duties of the office have been so ably performed by the Senior Vice-President, who, I rejoice to believe, is to be my successor. Under these circumstances, it would be a useless waste of your time for me to undertake to enlighten you in regard to matters with which the Senior Vice-President and the Secretary are so much better acquainted than I am.

My correspondence and my limited intercourse with the officers named, satisfy me that the financial affairs of the Society have

been very prudently managed—a vital necessity in these times, when so many institutions, as well as individuals, are struggling for existence. Could the Society own a suitable building for its meetings, library, and other purposes, it would, no doubt, be greatly relieved from restrictions that limit its usefulness. But, under present circumstances, it would seem almost a mockery to suggest such a thing; yet we believe the dawn of better times is upon us. The object is certainly most worthy, and the failure of a former effort in the same direction should not prevent the subject from being kept constantly in view. There are, no doubt, members of the Society—perhaps many—who feel very favorably disposed toward such an object, who cannot at present contribute anything, but who will, very probably, be relieved from existing embarrassments in the near future. Such persons might be induced to follow a custom so often practised with regard to other institutions—that is, to provide something for a building fund in their wills, with the intention, however, of being their own executors as soon as circumstances will permit. Others—and it is believed there are at least a few such—are abundantly able to give now, and would willingly do so if they felt assured their contribution would be put into the hands of such a responsible and permanent board or commission as would secure the faithful application of their funds—or returned to them or their heirs, in case a sufficient amoun should not be raised for the purpose.

The same causes that have prevented me from attending the meetings of the Society have also prevented me from making myself sufficiently acquainted with the general condition and progress of Civil Engineering in this and other countries to enable me to present the subject in a satisfactory manner. To simply repeat what others have already said on the subject would not be worthy of your time.

Allow me, gentlemen, to express not only my heartiest wishes for the prosperity and usefulness of the Society and for the happiness of its members, but my belief that it is to participate in the achievements and honors that await our profession in the early future.

With great respect,

E. S. Chesbrough.

MEMOIRS OF DECEASED MEMBERS.

CHARLES RIDGELY SCHOTT,* Member A. S. C. E.

Died July 9th, 1878.

Charles Ridgely Schott, was born in Baltimore, Maryland, on November 11th, 1847. He graduated at the Rensselaer Polytechnic Institute, as Civil Engineer in 1868, and was immediately appointed Assistant Engineer on the Hannibal and St. Joseph Railroad, in which position he was engaged on a variety of construction and other work until February, 1869, when he was promoted to the charge of a division, including the Quincy Bridge across the Mississippi river. In June, 1870, he left this position in consequence of malarial fever and was engaged as an Assistant Engineer on the Kansas Pacific Railroad, in topographical work and construction until February, 1871, when he was transferred to the charge of the Chief Engineer's office at Lawrence.

Returning to the East shortly after, he was in the employ of the Boston Franklinite Company until August, 1871, when he was appointed

* Committee to prepare memoir, J. James R. Croes and John Bogart.

an Assistant Engineer in the Topographical Bureau of the Department of Public Parks. During his service in this position he conducted a very thorough triangulation of the Harlem river and Spuyten Duyvil Creek, and was also engaged on the topographical surveys of the territory since annexed to the City of New York.

In June, 1874, he was promoted to the position of Division Engineer, and after December, 1875, was virtually the principal assistant on the work of laying out streets, etc.

The gradual advances of pulmonary disease, which was hereditary in his family, compelled him to relinquish active duty in his office in January, 1878, and at length terminated his life on the 9th day of July, 1878.

In all the positions to which he was assigned, Mr. Schott won the respect and regard of his superiors by his strict attention to his duties and the more than ordinary intelligence displayed in their performance. These qualities, in addition to the strict integrity of his character, seemed to give promise of his attaining a prominent rank in the profession, when his career was brought to an untimely end by disease.

Mr. Schott was elected a member of the Society, April 1st, 1874.

LIST OF NEW BOOKS ON

ENGINEERING AND TECHNOLOGY.

Architecture. Palliser's Model Houses, with designs for dwellings, barn, hennery, stable, carriage-house, school-house, bank, library, town-hall and three churches. 2d ed. rev. 8vo, illus. Bridgeport, Conn. *Palliser & Co.* $1.00.

Building Construction — Masonry. R. Scott Burn. London. 2 vols. Text. 2s. 6d. Plates, 5s. *Collins.*

——— Carpentry. R. Scott Burn. London. 2 vols. Text, 2s 6d. Plates, 4s. *Collins*

Campaign of 1776 around New York and Brooklyn, with circumstantial account of the battle of Long Island. H. P. Johnston. Brooklyn, N. Y. 8vo. 6 maps. 4 por. *Long Island Historical Society.* $4.00.

Carriage Act — Metropolitan Public. 1869 (32 and 33 Vict. c. 115), and Order made by the Secretary of State, 10th March, 1871; together with Abstract of Laws relating to Proprietors, Drivers, and Conductors of Public Carriages, and Penalties for Misconduct. With Appendix of Additional Statutes, &c., and Copious Index. Fcap., 8vo. London. *Government Publication.* 4d.

Casting and Founding, Practical treatise on ——— incl. descriptions of modern machinery employed. N E. Spretson. London and New York. 8vo, illus. *Spon.* $7.00.

Ceramic Art, a compendium of the history and manufacture of pottery and porcelain. J. J. Young. New York. 8vo, illus. *Harpers.* $5.00.

Colleges, American —: their students and their work. C. F. Thwing. New York. 16mo, *Putnams.* $1.00.

——— The American ——— and the American Public; with afterthoughts on College and School Education. Noah Porter. New York. 12mo. *Stribners.* $1.50.

Conferences held in connection with the Special Loan Collection of Scientific Apparatus, 1876; Chemistry, Biology, Physical Geography, Geology, Mineralogy and Meteorology (South Kensington Museum). Post, 8vo. London. *Chapman & Hall.* 6s.

Conferences Held in Connection with the Special Loan Collection of Scientific Apparatus, 1876; Physics and Mechanics (South Kensington Museum). Post 8vo. London. *Chapman & Hall.* 6s.

Crystallography. H. P. Gurney. London. 8vo, illus. *Soc. Prom. Chris. Know.* 1s.

Cyclopædia, Domestic ——— of practical information. T. S. Goodholme. New York 8vo, illus. *H. Holt & Co.* $5 00.

Drawing, Elementary course of Geometrical ——— George L. Vose. Boston, 4to, illus. *Lee & Shepard.* $5.00.

Engines, Examples of Steam, Air, and Gas Engines of the most Approved Types, as Employed in Mines, Factories, Steam Navigation, Railways, and Agriculture, Practically Described. With an Account of all the Principal Projects for the Production of motive Power from Heat which have been propounded in different Times and Countries. 54 Plates, and 356 Woodcuts. John Bourne. London. 4to. *Longmans.* 70s.

Encyclopædia — Analysis of Zell's ———. T. W. McClintock. Philadelphia. Fol. *Zell, Davis & Co.* $2.50.

Governor, The ———. Sir T. Elyot. Edited with notes, glossary, &c., by Herbert Croft. London. 2 vols. Small 4to. *C. K Paul & Co.*

Highways and Bridges, Chambers (G. F.) The Law relating to—being the Statutes in full, and Brief Notes of 700 Leading Cases, in a convenient form for reference, For use of Officers of Municipal Corporations, Local Boards, and Highway Boards, and of Justices' Clerks. To which is added the Law relating to Lighting of Rural Parishes under the "Lighting Act, 1833." G. F. Chambers. London. 8vo. *Stevens & Sons.* 18s.

Machine Construction. Edward Tomkins, edited by Henry Evers, London 2 vols. Text. 3s. 6d. Plates 7s. *Collins.*

Mechanic. The Universal Assistant and complete———. R. Moore. New York. 12mo. illus. *Albert Cogswell.* $2.50

Military Sketching and Reconnoissance—by Lieut. Col. F. J. Hutchison and Capt. H. G. Macgregor—(being Vol. 1, of Military Handbooks for Officers edited by Lieut. Col. C. B. Brackenbury. R. A.) London. Small 8vo. *C. K. Paul & Co.* 6s.

Mineral Statistics of the United Kingdom for 1877. Memoirs of the Geological Survey. R. Hunt. London 8vo. *Longmans.* 2s.

Newspaper—American ——— directory with lists of all the newspapers and periodicals published in the U. S , territories, Canada and Newfoundland; with description of the towns and cities in which they are published. October, 1878. New York. 8vo. *G. P. Rowell & Co.* $0.50.

Oxford. Its Social and Intellectual Life. With remarks and Hints on Expenses, the Examination. the Selection of Books, etc. Algernon M. M. Stedman. New York 12mo. *Scribner & Welford.* $3.75.

Paris International Exhibition, 1878: Coal and Iron in all Countries of the World. Compiled from Official Sources, and with the assistance of eminent living Authorities. Job Pechar. London. 8vo. *Heywood.* 5s.

Steam Boilers: their strength, construction and economical working. Robert Wilson. London. 5th ed. 12mo. illus. *Crosby Lockwood & Co.* 6s.

Steam Engine. A Course of Lectures on the Steam Engine, Delivered to the Students of Dynamical Engineering in the University of Pennsylvania. By Wm. D. Marks, Whitney-Professor of Dynamical Engineering. Philadelphia, 12mo. illus. *Lippincott.* (Announcement.)

Surveying—Howard (W. F.)Practice of Underground Surveying and Advocacy of Contoured Mining Plans, &c. With 5 tables and Diagram. W. F. Howard. London. 8vo. *Spons.* 2s.

Telegraph—Handbook of the Electro-Magnetic Telegraph. A. E. Loring. New York. 18mo. *Van Nostrand.* $0.50.

Water and Water Supply, chiefly in reference to the British Islands. Surface Waters. D. T. Ansted. London. 8vo. *W. H. Allen.* 18s.

Zuyder Zee—The dead cities of Holland. Henry Havard. Trans. by A Wood. New York. 12mo. illus. *Scribner & Welford.* $3.00.

ANNOUNCEMENTS.

The following resolution was adopted at the Ninth Annual Convention of the Society, and ordered printed regularly in the Society publications:

Whereas, the metric system of weights and measures is now extensively used abroad; and whereas, it is desirable that the relation of the units of differing systems be made familiar to all, by comparison:

Resolved, That Members be requested, in papers hereafter presented to the Society, to write, in parenthesis, weights or dimensions by the metric system, in connection with those of the system in general use.

The House of the Society is at 104 East Twentieth street, one door east from Fourth avenue, and near southwest corner of Gramercy Park. It is open from nine o'clock A. M. to five o'clock P. M. each business day except Saturday, when it is closed at three o'clock P. M.

The Library and Conversation Rooms will also, for the present, be open every *Thursday evening*, from 7½ to 10 P. M. Members are invited to avail themselves of the opportunities afforded on Thursday evenings both for consultation of books and periodicals and for conversation.

American Society of Civil Engineers.

PROCEEDINGS.

Vol. IV., September, 1878.

(Up to December 18th.)

MINUTES OF MEETINGS.

(Abstract of such as may be of general interest to members.)

OF THE SOCIETY.

NOVEMBER 20TH, 1878.—The Society met at 8 P. M., W. H. Paine in the chair.

A paper entitled "Submarine Telephoning," by Charles W. Raymond, was read by the author, and discussed by Messrs. G. S. Greene, Jr., Collingwood and Dresser.

A paper, by John Bogart, giving the results of enquiries addressed to engineers of railways in Great Britain as to the "Construction of Permanent Way," was read by the author, and discussed by Messrs. Andrews, J. C. Campbell, Chanute, Collingwood, Dresser, A. Fink, G. S. Greene, Jr., Haswell, Macdonald, W. H. Paine and Worthen.

DECEMBER 4TH, 1878.—The Society met at 8 P. M., Vice-President Roberts in the chair.

The ballots upon admission to membership were canvassed and the following candidates were declared elected: as members, James E. Childs, of Rochester, N. Y., and Malcolm S. Greenough, of Boston, Mass.; as Junior, Christopher L. Gates, of Milwaukee, Wis.

A paper, by D. McN. Stauffer, entitled "The use of Compressed Air in Tubular Foundations, and its application at South Street Bridge, Philadelphia," was read by the Secretary, and discussed by Messrs. Collingwood, Dresser, Macdonald, Roberts, Searles and Striedinger.

December 18th, 1878.—The Society met at 8 p. m., W. H. Paine in the chair.

A paper, presented at the annual meeting, as part of the Report of the Committee on Resistances of Trains, giving a record of the evaporative efficiency of certain locomotives as calculated by P. H. Dudley, was read, and discussed by Messrs. J. C. Campbell, Cooper, Forney, Haswell, Leverich, W. H. Paine and Worthen.

OF THE BOARD OF DIRECTION.

November 12th, 1878.—The Board met, organized, and the following standing committees were appointed:

On Finance: William H. Paine, C. Vandervoort Smith, George S. Greene.

On Library: Albert Fink, J. J. R. Croes, Thomas C. Clarke.

December 4th, 1878.—Applications for membership were considered. Business was transacted in reference to arrears of dues. Appropriations were made.

LIST OF NEW BOOKS ON

ENGINEERING AND TECHNOLOGY.

Astronomy. R. S. Ball. Specially revised for America by Simon Newcomb. New York. 16mo. *Holt & Co.* $0.60

Books. On the right use of them. Prof. W. P. Atkinson. Boston. 16mo, *Roberts Bro's.* $0.50.

Bridge and Roof Construction. Karl von Ritter. Trans. by Lieut. Sankey. London. *Spon.* (Announcement.)

Cabinet-Maker; the practical ——— ———; a collection of working drawings with explanatory notes. London. 8vo. *Wymans.* 4s.

Chart of the World, showing the Zoo-Geographical Regions according to Alfred Russell Wallace. By Dr. Andrew Wilson. Size 50 by 42 inches. Price, with Handbook, on rollers, varnished, 12s. *W. & A. K. Johnston,* Edinburgh and London.

Chemical Qualitative Analysis; a short course. Prof. John H. Appleton. Philadelphia. 12mo. *Cowperthwait & Co.* $0.90

Cleopatra Needle (The): Its Transport from Alexandria to London, and its Erection on the Thames Embankment. 1877-78. 3 Plates, 2 Diagrams. Copy of the Memorial Deposited in the Pedestal of the Cleopatra Needle, September 12th, 1878. Imp. 4to. *Engineering Office.* 1s.

Coal Mine Explosions. John Higson. London. 8vo. *Heywood* 7s. 6d.

Coal Mine Gases and Ventilation. J. Miller. London. Post 8vo. *Longmans.* 10s. 6d.

Electricity and Magnetism. Fleeming Jenkin. London. Fourth Ed., with Appendix on the Telephone and Microphone. Small 8vo, diagrams. *Longmans.* 3s. 6d.

Electric Lighting; its State and Progress, and its probable influence upon the Gas Interests. John T. Sprague. London. 8vo. *Spons.* 1s.

Friction and Lubrication, with new determinations of Laws and of co-efficients of Friction by new methods and with new Apparatus. Robert H. Thurston. New York. 12mo. *Railroad Gazette.* $1.50.

Health Manuals. London. Each 8vo. *Soc. Prom. C. K.*:
On Personal care of Health. E. A. Parkes, 1s.
Food. Albert J. Bernays. 1s.
Water, Air and Disinfectants. W. N. Hartley. 1s.
Health and Occupations. B. W. Richardson. 1s.

Hydraulics. Work done by, and power required for fire streams; together with tables and information rel. to hydraulics. Springfield, Mass. *G. A. Ellis*, 16mo, tucks. $1.75.

Hydrostatics and Pneumatics. Philip Magnus. (London Science Class Books.) 18mo. *Longman*. 1s. 6d.

Industries, British Manufacturing Industries, Metallic Mining. New ed. 12mo. London. *Stamford*. 3s. 6d.

Life Insurance, algebraic discussions of the principles upon which calculations of legal net money values in the business are based. G. W. Smith. New York. 8vo. *Van Nostrand*. $0.25.

Locomotive Engines: Embodying the Modern Practice of Locomotive Engineering. D. Kinnear Clark. Being an Enlargement of Dempsey's Treatise. London. *Crosby, Lockwood & Co.* (Announcement.)

London. Account of the Great Buildings of London. Historical and Descriptive. N. D'Auvres. Autotype, illus. *M. Ward & Co.* 6s.

Masonry and stone cutting. Rudiments of—E. Dobson. (Weales Series) New Ed. London. 12mo. illus. *Crosby, Lockwood & Co.* 2s. 6d.

Microscope, half hours with the——14th ed. With Chapter on the Polariscope by F. Kitton, and illustrations by Tuffen West. E. Lankester. London. 12mo. *Hardwicke & Bogue*. 2s. 6d.

Mississippi River. Review of Humphrey's and Abbot's rep. on the physics and hydraulics of the Mississippi river. Jas. B. Eads, New York. 8vo. Van Nostrand. $0.25.

Ornament: Polychromatic. 100 plates in gold, silver and colors. Comprising upwards of two thousand specimens of the various styles of Ancient, Oriental and Mediæval Art, and including the Renaissance and 17th 18th Centuries. With explanatory description to each plate, and a General History of the Art of Ornamentation. A. Racinet, London. Folio illns. *H, Sotheran & Co.* £6. 6s.

Painting. By Messrs. Crosby, Lockwood & Co. School of Painting for the Imitation of Woods and Marbles, as taught and practiced by A. R. and P. Van der Burg, Directors of the Rotterdam Painting Institution, London *Crosby, Lockwood & Co.* (Announcement.)

Public Works of East India. Report of select Committee, with evidence. *Parliamentary Publication*. 5s. 6d.

Pyrotechnists' Treasury; or complete art of making fireworks. Thomas Kentish. London. Crown 8vo. illus. Plates. *Chatto & Windus*. 4s. 6d.

Railway Accidents. Returns for half year to June, 1878. London. *Government Publication*. 1s. 3d.

Railways in East India; Danvers' Report, 1877-78. London. *Parliamentary Publication*. 2s.

Railway Ticket System. To Whom are We indebted for the Railway Ticket System. Reprinted from the "English Mechanic and World of Science," Aug., 1878. *Blacklock*. (Manchester). 6d.

Rule—Spiral Slide. Equivalent to a Straight Slide Rule, 83 feet 4 inches long, or a Circular Rule 13 feet 3 inches in Diameter (patent). Fcap. George Fuller. London. *Spons*. 6d.

Scientific Discovery. The art of——G. Gore. London Crown. 8vo. *Longmans*. 15s.

Science. Pleasant ways in——Richard A. Proctor. London. Crown 8vo. *Chatto & Windus*. 10s. 6d.

Signals—The Morse Universal Flashing——For use with the Commercial Code Signal Book in Foggy Weather, by means of a Single Lantern only. With twenty-one handy Night-Towing Signals. S. R. Elson. 8vo. *Thacker* (Calcutta). 1s. 6s.

Steam Engine. The Relative Proportions of the Steam Engine. A course of Lectures on the Steam Engine, delivered to the Students of Dynamical Engineering in the University of Pennsylvania. William D. Marks, Whitney, Professor of Dynamical Engineering. Philadelphia, 12mo, illus. *Lippincott*. $1.50.

—— ——. Text Book on the —— —— T. M. Goodeve. London, 8vo, illus. *Crosby, Lockwood & Co.*

Submarine Warfare, offensive and defensive, with discussion of the offensive torpedo system, its effects upon iron-clad ship systems, and its influence upon future naval wars. Lt. Com. J. S. Barnes, U. S. N. New York, 8vo, illus. 20 plates. *Van Nostrand*. $5.00.

Survey of Hull, Equipments and Machinery of Steam Ships carrying passengers. New ed. 1878. London, 8vo. *Pewtress*. 1s. 6d.

Surveyor's Main Road Account Book, adapted for Keeping the Separate Accounts of the Maintenance of Main Roads as required by the Highways and Locomotives (Amendment) Act. 1878. 4to, sd. *Leach* (Wisbech). *Simpkin* (London). 4s.

Tempering Scale. Color Tempering Scale, printed in colors, by the aid of which any one can accurately temper any tool. Full instructions on Hardening and Tempering by Joshua A. Rose. How to make the Telephone, Phonograph, and Microphone, together with other valuable information from the late volumes of *Scientific American*. New York. *Wiley & Sons*. $2.00.

Vapors, Report of Commission on Noxious Vapors. *British Government*. 6d.

Weaving, The History and Principles of Weaving by Hand and by Power, reprinted, with considerable Additions, from "Engineering," with a Chapter on Lace-making Machinery, reprinted from the "Journal of the Society of Arts." Alfred Barlow. London, 8vo, illus. *Low*. 25s.

Weaving by Hand and Power. The History and Principles of. Alfred Barlow. Philadelphia, 8vo. *Henry C. Baird & Co.* $10.00.

Wrinkles and Recipes. Edited by Park Benjamin, Ph. D. Contains, beside the large original collection of valuable trade recipes for all classes of Mechanics and Engineers 50 new pages of important wrinkles and trade secrets. New ed. rev. and enl. New York. *Wiley & Sons*.

ANNOUNCEMENTS.

Announcement of the publication of books, papers or articles by members of this Society is requested to be made to the Secretary.

The annual meeting of the American Institute of Mining Engineers will be held at Baltimore on the third Tuesday of February next.

The following resolution was adopted at the Ninth Annual Convention of the Society, and ordered printed regularly in the Society publications:

Whereas, the metric system of weights and measures is now extensively used abroad, and whereas it is desirable that the relation of the units of differing systems be made familiar to all by comparison:

Resolved, That members be requested, in papers hereafter presented to the Society, to write, in parenthesis, weights or dimensions by the metric system, in connection with those of the system in general use.

The House of the Society is at 104 East Twentieth street, one door from Fourth avenue, and near the southwest corner of Gramercy Park. It is open from nine o'clock A.M. to five o'clock P.M. each business day, except Saturday, when it is closed at three o'clock P. M.

The Library and Conversation Rooms will also, for the present, be open every *Thursday evening*, from 7½ to 10 P. M. Members are invited to avail themselves of the opportunities afforded on Thursday evenings both for consultation of books and periodicals and for conversation.

LIST OF MEMBERS.

ADDITIONS.

MEMBERS.

		Date of Election.
CHILDS, JAMES E.	Chief Engineer, Rochester and State Line R. R., Rochester, N. Y.	Dec. 4th, 1887
GREENOUGH, MALCOLM S.	Boston Gas Light Co., Boston, Mass.	" "

JUNIOR.

GATES, CHRISTOPHER L.	Ass't Engineer Chicago, Milwaukee and St. Paul R.R., Milwaukee, Wis.	" "

RESIGNATIONS.

EMSLIE, PETER	(Member)	Oct. 17th, 1878
FORD, JAMES K.	"	Oct. 12th, 1878
HINES, DAUPHIN S.	"	Oct. 10th, 1878

DECEASED.

REEVES, SAMUEL J.	(Member	Dec. 15th, 1878

American Society of Civil Engineers.

PROCEEDINGS.

Vol. IV., October, November and December, 1878.

MINUTES OF MEETINGS.

(Abstract of such as may be of general interest to members.)

[NOTE.—The number of the Society Transactions issued at this time is consecutively headed as that for October. 1878. The next number will be the descriptive memoir and statement made by the Committee on the exhibit of American Engineering in Paris in 1878, reported at the Annual Meeting and then ordered published in the Transactions of the Society. Its length is that of two ordinary numbers, and it will be issued as for the months of November and December.

The proceedings have been in fact brought up to the end of the year 1878, the minutes of all the meetings of that year having been printed. Below is given a short abstract of the proceedings of meetings held since the beginning of the year. A more detailed report will be published in the regular Proceedings issued for January.]

At the regular meeting of the Society, held January 3d, 1879, the vote upon amendments to the Constitution and By-Laws was canvassed, and the recommendations made at the Annual Meeting as to the adoption or rejection of the several amendments were in each case carried.

The President, W. Milnor Roberts, announced that he was about to visit Brazil, professionally, and made a short address. A committee was appointed and a preamble and resolutions reported by it on the subject of the departure of the President were adopted.

At the meeting of January 15th, the subject of discussion was Resistances of Rolling Stock.

At the meeting of February 5th, the ballots for place of next Convention were canvassed, and it was found that the City of Cleveland had a majority of the votes. William H. Bradley, of Boston, and Hamilton Smith, Jr., of San Francisco, were elected members.

A paper on the Electric Light was read by Stephen Chester.

At the meeting of February 19th, a paper on Gelatine Dynamite was read by Julius H. Striedinger.

LIST OF NEW BOOKS ON

ENGINEERING AND TECHNOLOGY.

Architecture. A Handbook of Formula Tables and Memoranda for Architectural Surveyors and others engaged in Building. 12th ed., re-written and enlarged. John Thomas Hurst. London. 32mo. *Spons.* 5s.

Arithmetic. Intuitive Calculations, or Easy and Compendious Methods of Performing the various Arithmetical Operations required in Commercial and Business Transactions. (Weale's Series.) 25th ed, corrected and enlarged by J. R. Young. Daniel O'Gorman. London. 12mo. *Crosby Lockwood.* 3s. 6d.

Car Builder's Dictionary. New York. 8vo. *Railroad Gazette* (Announcement.) $1.75.

Cast Iron Pipes. Ernest Benedict. London. 8vo. *Spons.* 6d.

Centennial Exhibition. Official Report descriptive of the Grounds and Buildings of the U. S. International Exhibition. Illustrated with Views of the Buildings and their Ground Plans, and the Official Situation Plans. Imperial 8vo. *Lippincott.* $5.00.

Chemistry. Elements of Modern Chemistry. Ad. Würtz. Paris. Trans. and Ed. by Wm. H. Green. Philadelphia. Illus. *Lippincott.* (Announcement.)

——— A Treatise on Chemistry. Professors Roscoe and Schorlemmer. Manchester. Vol. II. Metals. Illus. *Appleton.* (Announcement.)

Coal: its History and Uses, by Professors Green, Mial, Thorpe, Rücker and Marshall. New York. 8vo. *Macmillan.* $4.

——— The History of Coal; a Lecture at Kings College. Thomes Wiltshire. London. 8vo. *Spons.* 1s.

——— Mine Gases, Ventilation, and Gases inclosed in coal. J. W. Thomas. London. 8vo. *Longmans.* 10s. 6d.

Compressed air: Transmission of power by ——— ———. Rob. Zahner. New York. Van Nostrand, Science Series No. 40. *Van Nostrand.* $0.50.

Dictionary of Scientific Terms. William Rossiter. London. 8vo, illus. *Collins.* 3s. 6d.

Drawing Instruments. Treatise on Mathematical ——— ——— with hints on coloring and drawing. W. F. Stanley, New York, 5th ed. 8vo, illus. *Spons.* $2.40.

Elasticity—from "Encyclopedia Buttanica." W. Thomson. Edinburgh. 4to. *Black.* 4s.

Electric Lighting; its state, progress and probable influence on gas interests. J. T. Sprague. New York. 8vo. *Spon.* $0.40.

——— ——— on the present state of; J. N. Shoolbred, London. 8vo. *Hardwicke.* 1s.

——— Light; its past history and present position. T. C. Hepworth. London. 12mo. illus. *Routledge.* 1s.

——— ——— An Illustrated Guide to its Production, Cost and Practical Application. With Descriptions of the various Inventions now before the Public. London. 12mo. *Ward and Lock.* 1s.

Encyclopedia of Civil Engineering; Cresy's. I vol. 8vo. Longman, London. *Worthington, New York.* $13.50.

Engineers; Aide-Memoire for the use of officers of Royal Engineers. Compiled by Colonel A. C. Cooke, C. B., R. E, with Contributions and Assistance from other Officers Vol. I. Formulæ, Tables, Military Statistics, and Memoranda for the Field. London, 8vo. *Government Publication.* 12s. 6d.

——— Calvert's Pocket Book and Annual for Engineers, Mechanics and Builders. London. 12mo. *Heywood.* 1s.

Engines, Single and Compound; their relative merits. Portsmouth, England. *Griffin.* 4s. 6d

Field Engineer. A Handy Book of Practice in the Survey, Location and Track Work of Railroads. William Findlay Shunk, C. E., Chief Engineer of the Construction of the Metropolitan Elevated R. R., New York. *Van Nostrand.* (Announcement.)

Gas. The history, manufacture, distribution and economical consumption of coal-gas; a lecture by Samuel Hunter. Manchester, England. 8vo. *Cornish.* 1s

Gunpowder and Gun Cotton; notes on. *British Government publication, London.* 1s.

Gun, ram and torpedo; with diagrams and illustrations. Portsmouth, England. *Griffin.* 8s. 6d.

Hampton Tracts. Condensed Statements of the Fundamental Laws of Health. Comprising: No. 1, Health Laws of Moses; No. 2, Duty of Teachers; No. 3, Preventable Diseases; No. 4, Who Found Jamie; No. 5, A Haunted House. Edited by Stephen Smith, M.D., General S. C. Armstrong, Miss H. W. Ludlow, and others. 16mo. *Putnam.*

New York. 8c. per number; $5 per hundred; $40 per thousand.

Heat. An elementary treatise on Heat. Wm. Garnett. 2d ed., rev. and enl. London. 8vo. *Bell.* 3s. 6d.

Health, Dangers to ——. A practical guide to domestic sanitary defects. T. P. Teale. London. 8vo. *Churchill.* 10s.

Healthy Houses. Fleeming Jenkins. Edinburgh. 8vo. Plates. *Douglas.* 2s. 6d.

Health Primers. Edited by eminent medical and scientific men of London.

1. Alcohol, its use and abuse. W. S. Greenfield, M. D.
2. Exercise and Training. C. H. Rolfe, M.D.
3. Premature Death ; its promotion or prevention.
4. The House and its Surroundings.

Square 16mo. *Appleton.* New York. Each $0.40.

—— ——. Edited by J. Langdon Down, Henry Power, J. Mortimer-Granville, and John Tweedy. Alcohol, its use and abuse. The House and its Surrounding. Exercise and Training. Premature Death ; its promotion and prevention. London. Foolscap. 8vo. (Same as above. English edition.) *Hardwicke & Bogue.* Each 1s.

Hydraulic Engineering. The Hempstead Storage Reservoir of Brooklyn: its engineering theory and results. Samuel McElroy. New York. 8vo. *Van Nostrand.* $0.50.

Hydrometir, Manual of ——. 2d ed., illus. Portsmouth, England. *Griffin.* 3s. 6d.

Hydrostatics and Pneumatics. P. Magnus. London Science Class-books. 18mo. *Longman's.* 2s.

Map Drawing. A. Gardiner. London. 4to. *Hughes.* 1s.

Mechanics. Appleton's Cyclopedia of applied Mechanics. New ed. Ed. by P. Benjamin. New York. *Appleton.* (Announcement.)

Metal Work : A series of more than 1,200 of the best Examples which have attracted attention at the various International Exhibitions, with treatises on the principal Industries which have produced them. By G. W. Yapp, Assistant Commissioner, and Compiler of the Official Catalogues of the Great English International Exhibition. London. Imp. 4to. *Virtue & Co.* £2 5s.

Mineralogy and Lithology, A manual. Prof. James D. Dana. New York. 12mo. *Wiley's.* $2.00.

New York Illustrated. 4to. *Appleton.* $0.60.

Railways, Continuous Brakes. Return. London. *British Parliamentary Publication.* 6d.

Science for all. Edited by Robert Brown. Vol. I. Illustrated. London. Roy. 8vo. *Cassell.* 9d.

Ship—The Polyspheric ship and speed at sea. C. M. Ramus. London. 8vo. *Stanford.* 1s. 6d.

—— The War Ships of Europe. Illus. Portsmouth, England. *Griffin.* 10s. 6d.

Statics and Hydrostatics, Elementary. J. Hamblin Smith. London. 8vo. *Rivingtons.* 6s.

Steam and Steam Engines, Land, Marine and Locomotive. Henry Evers. 3d ed., rev. and enl. (Collins' advanced Science Series.) London. 12mo. *Collins.* 3s.

Steam Engine ; Manual of the —— —— and other prime movers. W. J. M. Rankiue. 9th ed., revised by W. J. Millar. London, 8vo. *Griffin.* 12s. 6d.

Steam Vessels. Power and speed of —— —— Calculated by rules adopted for vessels of all types. W. Bury. New York, 8vo. *Spons.* $1.40.

Stevenson. Life of Robert Stevenson, Civil Engineer. D. Stevenson. New York, 4to. Plates. *Spons* $8.00.

Surveying—Nautical —— from "Alston's Seamanship." Portsmouth, England. *Griffin.* 2s. 6d.

Telephone; the Speaking Telephone, Electric Light, and other recent electrical inventions. George S. Prescott. New edition enlarged, with illustrated descriptions of Edison's inventions. New York, 8vo, illus. *Appleton.* $4.00.

Telegraph—Instructions for Testing Telegraph Lines, and the Technical Arrangements of Offices. Written on behalf of the Government of India, under the Orders of the Director-General of Telegraphs in India. Vol. I. L. Schwendler. London, 8vo. Trubner. 12s.

—— The Telegraph in America; its promoters and noted men. J. D. Reid. New York, 8vo, illus. *Derby Bros.* $6.00.

ADDITIONS TO

LIBRARY AND MUSEUM.

From Administration des Ponts et Chausees, Paris:

Annales, September, October, November, December, 1878.

From Aeronautical Society of Great Britain, London ;

Fred. W. Breary, Hon. Secretary. Reports from 1866 to 1877, inclusive.

From American Chemical Society, P. Cassamajor, Secretary, New York :

Proceedings, Vol. I. and Nos. 1, 2 and 3, Vol, II.

From American Institute Mining Engineers, Thomas M. Drown, Secretary, Easton, Pa.:

An Improved Universal Suspended Hydraulic Lift. J. A. Herrick. Easton, Pa, 1879.

Imperfections in Surveying Instruments. J. Hy. Harden. Easton, Pa. 1879.

New Determinations of the Coefficients of friction of Lubricated Journals, and on the laws governing such friction. R. H. Thurston. Easton, Pa. 1878.

Notes on the Result of an Experiment with the Wheeler Process of combining Iron and Steel in the head of a Rail. W. E. C. Coxe, Easton, Pa. 1878.

Proceedings of the Meeting at Lake George and Lake Champlain. Easton. Pa. 1878.

The Butler mine fire Cut-off. H. S. Drinker. Easton, Pa. 1879.

The Heat of the Comstock Mines. Prof. J. A. Church. Easton, Pa. 1878.

The Jenks Corundum Mine. Macon Co., North Carolina. R. W. Raymond. Easton, Pa. 1878.

The Mechanical work performed in heating the Blast. Prof. B. W. Frazier, Easton, Pa. 1878.

From American Iron and Steel Institute. James M. Swank, Secretary, Philadelphia :

Directory to the Iron and Steel Works in the United States, corrected to September 1st, 1878. Philadelphia. 1878,

From Edward R. Andrews. Boston :

The Teredo and its depredations. Extract from the Archives of Holland. Vol. 1. Translated by Edward R. Andrews. New York. 1878. (Copies for Distribution.)

Two Photographs of a Creosoted Railway Sleeper, twenty years in use on the North Eastern Railway of England.

From Argentine Scientific Society. D. Felix Amoretti, Secretary, Buenos Ayres :

Annals of the Society. August, October, November, 1878.

From Austrian Society of Engineers. E. R. Leonhardt, Secretary, Vienna :

Wochenschrift and Zeitschrift of the Society, from March to June, 1878, inclusive.

From John W. Bacon, Danbury, Conn.:

Twenty-sixth Annual Report of the Railroad Commissioners of Connecticut. Hartford, Conn. 1878.

From Gen. John G. Barnard, U. S. A., New York ;

Report of the Board of Officers appointed to examine the works in progress of construction by James B. Eads, at the mouth of the Mississippi River. Washington. 1879.

From Gen. S. V. Benet, Chief of Ordnance, U. S. A., Washington :

Annual Report of the Chief of Ordnance, 1878. Washington. 1878.

From Charles E. Billin, Philadelphia :

Report of Progress in the Juniata District, on the Fossil iron ore beds of middle Pennsylvania. John H. Dewees. Harrisburgh, Pa. 1878.

From Boston Public Library;

Bulletin of Library. October. 1878. Boston.

From British Board of Trade, London :

British Trade Journal. September 1st, 1878. London.

From W. D. Bullock, Pawtucket, R. I.:

Lithograph, Corliss' Pumping Engine. New York. 1878.

From Bureau of Education, Washington :

The training of Teachers in Germany. Washington. 1878.

From Bureau of Navigation, Washington :

The American Ephemeris and Nautical Almanac, for the year 1881. Washington. 1878.

From Hon. Allan Campbell, New York:

Reports of the Department of Public Works, of the City of New York. Quarters ending June 30th and September 30th, 1878. Allan Campbell, New York 1878.

From E. S. Chesbrough. Chicago.

Second Annual Report of the Department of Public Works of Chicago. E. S. Chesbrough. Chicago. 1878.

From Civil Engineers Club of the Northwest. L. P. Morehouse, Secretary. Chicago;

Economical Height and minimum material in Bridges of various designs. C. H. Tutton. Chicago. 1878.

On the Improvement of Prairie Roads and Streets. T. J. Nicoll. Chicago. 1878.

From Francis J. Cisneros, Puerto Berrio, U. S. of Colombia;

Report on the Construction of the Antioquia Railroad. F. J. Cisneros. New York. 1878.

Report on the Construction of the Cauca Railway. (U. S. Colombia). F. J. Cisneros. New York. 1878.

From H. Wadsworth Clarke, Syracuse, N. Y.

Mayor's inaugural address and reports of Department of the City of Syracuse. 1877-78. Syracuse. 1878.

Report of the Pennsylvania Board of the Pennsylvania, Ohio and West Virginia. Boundary Commission for 1878. Harrisburg. 1879.

From Commissioners of Second Geological Survey of Pennsylvania. W. A. Ingham, Secretary. Philadelphia:

Catalogue of the Geological Museum. Chas. E. Hall. Harrisburg. 1878.

Report of Progress in the Beaver River District of the Bituminous coal fields of Western Pennsylvania. I. C. White. Harrisburg, Pa. 1878.

Report of Progress in the Fayette and Westmoreland District of the Bituminous coal fields of Western Pennsylvania. J. J. Stevenson. Harrisburg. 1878.

Report of Progress in the Juniata District, on the Fossil Iron ore beds of middle Pennsylvania. J. H. Dewes. Harrisburg. 1878.

Special report on the Trap Dykes and Azoic Rocks of Southeastern Pennsylvania. T. Sterry Hunt. Harrisburg. 1878.

The Brown Hematite Deposits of the Siluro-Cambrian Limestones of Lehigh Co. F. Prime, Jr. Harrisburg. 1878.

Two hundred Tables of Elevation above Tide-Level of the Railroad Stations, Summits and Tunnels ; Canal locks and Dams, River Riffles, &c., in and around Pennsylvania. Charles Allen. Harrisburg. 1878.

From J. D. Cooke. Toledo. Ohio.

Annual reports of Toledo Water Works from 1873 to 1877 inclusive.

From J. James R. Croes. New York:

An Act incorporating the Newark, N. J. Aqueduct Board. Newark, N. J. 1860.

Constitution and By-laws of the Newark, N. J. Aqueduct Board. Newark, N. J. 1860.

Reports of the Newark, N. J. Aqueduct Board from 1870 to 1877 inclusive.

Some notes on Sewers. J. J. R. Croes. New York. 1879.

From Joseph P. Davis, Boston:

Second Annual Report of the Boston Water Board, year ending April 30th, 1878. Boston. 1878.

From C. P. Dudley, Philadelphia:

The Chemical Composition and Physical Properties of Steel Rails, and does the wearing power of Steel Rails, increase with the hardness of the steel? C. P. Dudley, Philadelphia. 1878.

From H. T. Eddy. New York:

A new General Method in Graphical Statics. H. T. Eddy, C. E. Ph. D. New York. 1878.

From Civil Engineers Club of Philadelphia. Charles E. Billin, Secretary. Philadelphia:

Constitution and By-laws of the Civil Engineers Club of Philadelphia. Philadelphia. 1879.

Memorial of the Engineers Club of Philadelphia and Citizens of the State of Pennsylvania to the members of the Senate and House of the Representatives. 1878-9. Philadelphia. 1878.

On the proposed removal of Smith's Island. Prof. L. M. Haupt. New York. 1878.

Water Supply to a Stamp Mill in Venezuela with notes on Kutter's formula. Wm. A. Biddle. New York. 1878.

From Joseph Fales, Troy, N. Y.:

Twenty-third Annual Report of the Water Commissioners of Troy. Troy. 1878.

From Charles E. Fowler, New Haven, Conn.:

Proposal for Superstructure of Lewis' Bridge, over Quinnipiac River, at the crossing of Middletown Avenue, between New Haven and East New Haven, Conn. New Haven, Conn. 1878.

From Franklin Institute. Philadelphia:

Journal of the Institute for October and November 1878. Philadelphia. 1878.

From George H. Frost, publisher Engineering News, New York:

Bearing Piles. R. Hering, Chicago. 1878.

Description of Boston Water Works. Chicago. 1878.

Humber's Water Supply for Cities and Towns. Parts 1, 2, 3. Chicago. 1878.

From Fred. de Funiak, Louisville, Ky.:

Itemized Statement of Car repairs and expenses of Louisville and Nashville and South and North Alabama Railroads, year ending June 30th, 1878. Louisville. 1878.

From David M. Greene. Troy, N. Y.:

Twenty-third Annual Report of the Water Commissioners of the City of Troy, for the year 1877. Troy. 1878.

From George S. Greene, Jr., New York:

Annual Report of the Department of Docks, City of New York, 1878. New York. 1878. (4 copies.)

From B. M. Harrod, New Orleans:

The Levees of Louisiana—their condition and requirements. B. M. Harrod. New Orleans. 1878. (3 copies.)

From Hartford Steam Boiler Inspection and Insurance Company, Hartford:

Annual Reports for 1877 and 1878.

From John W. Hill, Cincinnati:

On the Explosion of the Steamer Pat. Cleburne. J. W. Hill. New York. 1878.

From Gen. A. A. Humphreys, Chief of Engineers, U. S. A., Washington, D. C.:

Statement showing Rank, Duties and address of Officers of the Corps of Engineers. George H. Elliot.

Annual Report on the Improvement of the South Pass, showing condition of the works, June 30th, 1878. Capt. M. R. Brown. (Copies for distribution.)

Estimates of amount required for the protection from overflow of the sites of fortifications on the Delaware River, and also an estimate of the cost of repairs at Sandy Hook, New Jersey. William Ludlow.

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U. S. Geological Exploration of the Fortieth parallel. Systematic Geology. Vol. 1. Clarence King.

From Institution of Civil Engineers of Ireland. John C. Smith, Secretary, Dublin :

By-Laws and Regulations of the Institute. Dublin, 1874.

From Institution of Civil Engineers, publications edited by James Forrest, Secretary, London, as follows :

Minutes of Proceedings, Vols. LIII, and LIV. London, 1878.
Abstract of papers in Foreign Transactions and Periodicals. Part 4. 1877-8.
Bridges on the Punjab Northern State Railway :
Ravi Bridge. R. T. Mallet.
Alexandra Bridge. Henry Lambert.
The Thelum Bridge. F. M. Avern.
The Chalk Water Supply of Yorkshire. J. R. Mortimer.
Coal Washing Apparatus of Besseges, France. J. B. Marsant.
The Construction of Steam Boilers adapted for very high pressure. James F. Flannery.
The Design generally of Iron Bridges of very large span for railway traffic. Thomas C. Clarke.
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Experiments on the Heights of Jets from the hydrants of the Kingston Water Works, Jamaica. Felix Target.
Note on the Eddystone Lighthouse. James N. Douglas.
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Portland Cement Concrete. John W. Sandeman
Report of the Proceedings at the Annual Meeting of the Institute, December 18th, 1878.
A Skeleton Pontoon Bridge. B. W. Blood.
The Victoria, Albert and Chelsea embankments of the River Thames. Edward Bazalgette.

From the Institution of Engineers and Shipbuilders. W. J. Millar, Secretary, Glasgow, Scotland :

Transactions of the Institute. Vol. XXI., 1878.

From the Institution of Mechanical Engineers. Walter R. Browne, Secretary, London;

Proceedings, June and October, 1878.

From John B. Jervis, Rome, N. Y.:

A Lecture on Industrial Economy. John B. Jervis. Rome, N. Y., 1878.

From Thomas H. Johnson, Indianapolis, Ind.:

Report of Proceedings of the Board of State House Commissioners of Indianapolis, from date of organization, December 31st, 1878. Indianapolis, 1879 (3 copies).

From John A. Judson, Newport, R. I.:

Map of Battle Grounds of August 28th, 29th, and 30th. 1862, in the vicinity of Groveton, Prince William Co., Va. Washington, 1878.

From William Kent, Pittsburg:

The Strength of Materials. Wm. Kent, New York, 1879.

From M. Ch. Laboulaye, Paris :

Prospectus dictionaire des Arts et Manufactures et de l'Agriculture. Ch. Laboulaye. Paris, 1878.

From Charles Latimer, Cleveland, O.:

Comparative Statement of Expenses in Engineering Department, Atlantic and Great Western Railroad, June, 1877-78. Cleveland, 1878.

From M. Edward Lavoiune, Auxerre, France :

Notice sur les Principaux systèmes de Locomotives sans feu. E. Lavoinne. Paris, 1878.

From E. D. Leavitt, Jr., Cambridgeport, Mass.:

Third Annual Report of the Lawrence Water Board. Lawrence, 1879 (2 copies).

From F. Leypoldt, New York :

The Library Journal, No. 10, Vol. III., New York, 1878.

From W. H. Lotz, Chicago :

Plain and ornamental Stone Work, Floor tiling and Cement sidewalks. Hall and Salisbury, Chicago, 1878.

From M. Malezieux, Paris, France :

Les Travaux Publics aux Etats Unis d'Amerique. Conference faite au Palais du Trocadero le 7 Aout, 1878. M. Malezieux. Paris, 1878.

From W. J. McAlpine, Babylon, N. Y.:
Annual Report of the Auditor of the Canal Department on the Tolls, Trade and Tonnage of the Canals of State of New York. George W. Schuyler, Albany, N. Y., 1878. (Copies for distribution.)

From Wm. H. McFadden, Philadelphia;
Annual Report of Department for supplying the City of Philadelphia with water. Philadelphia, 1878.
Annual Reports of Philadelphia Water Department from 1873 to 1877, inclusive. Philadelphia, 1878.

From Niles Meriwether, Fayette, Miss.:
Third and Fourth Annual Reports of the officers of the Tuscumbia, Courtland and Decatur R.R. Co. Tuscumbia, Ala., 1836.

From Minister of Public Works, Mexico:
Anales del Ministerio de fomento de la Republica Mexicana. Mexico, 1878.

From George S. Morison, New York:
The Forty-first Annual Report of the Eastern Railroad Co. Boston, 1876.
The Forty-third Annual Report of the Eastern Railroad Co. Boston, 1877.

From Robert Moore, St. Louis;
The Mayor's Message, with accompanying Documents to the Municipal Assembly of St. Louis. St. Louis, 1878.

From Edward P. North, New York:
Atlantic Giant Powder Co. *vs.* George M. Mowbray *et al.* Pleadings and evidence in Circuit Court of Massachusetts. Boston, 1876.
Major-General Hazen on his post of duty in the great American Desert, reviewed by an ex-Surveyor-General. New York, 1874.
Sewage Irrigation by Farmers. R. W. Peregrine Birch. London, 1878.

From the North of England Institute of Mining and Mechanical Engineers, Theo. Wood Bunning, Secretary, Newcastle-on-Tyne, England:
Transactions of the Institute. Vol. XVII. 1877–8.
Transactions of the Institute. June, July, August, September, October, November. 1878.

From John C. Palfrey, Boston:
Frizell's Patent Air Compressor. Boston. 1878. (Copies for distribution.)

From Ernest Pontzen, Paris, France:
Fabrique de Compteurs d'Eau. A. C. Spanner. Vienna. 1878.

From the Portuguese Society of Civil Engineers, Lisbon, Portugal:
Review of Public Works and Mines. August, 1878.

From A. C. Rand, New York:
Rock Drills and Air Compressors. Rand Drill Co. New York. 1878.

From Charles W. Raymond, New York:
Thirteen Photographs, illustrating Boats, Dredges, &c., used in construction by the Department of Docks of the city of New York.

From John Reed, Paterson, N. J.:
Photographs of—
Albany upper bridge, built by Leighton Bridge Co. John F. Alden, Engineer, Rochester, N. Y. Springfield bridge, built by Leighton Bridge Co. John F. Alden, Engineer, Rochester, N. Y. Passaic River bridge, at Newark, N. J., built by Delaware Bridge Co. Chas. Macdonald, Engineer. New York. Raritan Draw bridge, built by Keystone Bridge Co. J. H. Linville, Consulting Engineer, Philadelphia. Portage bridge, built by Watson Mfg. Co. Geo. S. Morison Engineer. New York.

From the Publishers, Revue Generale des Chemins de fer, Edgar Monjean, Secretary, Paris, France:
Revue Generale des Chemins de fer, August, September, October and November, 1878.

From Francis Rinecker, Wuerzburg, Germany:
Die Virtuelle Länge unde ihre Andwendung auf Bau und Betrieb du Eisenbahnen. A Lindner. Zurich. 1879.

From A. Q. Ross, Cincinnati:
The Ross combined Steam Ram and Road Roller. Cincinnati. 1875.

From the Royal United Service Institution, Capt. B. Burgess, Secretary. London, England:
Journal of the Institute. Vol. XXII. 1878.
Index of the Lectures in the Journals. Vols. XI–XX.

From the Saxonian Society of Engineers and Architects, Dresden, Germany;
Transactions of the Society, 1878.

From J. Herbert Shedd, Providence, R. I:
Report of Special Committee on sewerage of the city of Taunton, with report and proposed plan. Taunton, Mass. 1878. (Copies for distribution.)

From the Smithsonian Institution, Washington:
Annual Report of the Institution for 1877.

From the Societé des Ingenieurs Civils, Paris, France:
Transactions of the Society. May and June, 1878.

From Thomas D. Stetson, New York:
Argument in behalf of Bernard Ackerman, before the Honorable Commissioners of Patents, in the case of Ackerman *vs.* Archer. Thomas D. Stetson. New York. 1878.

From Thomason Civil Engineering College, Major A. M. Brandreth, Offg. Principal. Roorkee, India:
Professional Papers on Indian Engineering. January, April, July and October, 1878.
Index to Professional Papers on Indian Engineering. First Series, Vols. I–VII. Second Series, Vols. I–V.
Catalogue of books printed and published at the Thomason College press. (4 copies.)

From R. H. Thurston, Hoboken, N. J.:
A History of the growth of the Steam Engine. Prof. R. H. Thurston. New York, 1878.
Report on Cold-rolled Iron and Steel, as manufactured by the American Iron Works of Pittsburg. Prof. R. H. Thurston. Pittsburg. 1878.

From Charles Truesdell, Syracuse, N. Y.:
Proposal. Contract and Specifications for building a distributing Reservoir, Syracuse Water Works. Syracuse. 1878.

From the U. S. Light House Board, Washington:
Annual Report of the Light House Board for 1878. List of Towers, Beacons, Buoys

Stakes and other Day Marks in the Sixth Light House District, (2 copies.)

List of Towers, Beacons, Buoys, Stakes and other Day Marks in the Seventh Light House District. (5 copies.)

From D. Van Nostrand, New York:

Van Nostrand's Engineering Magazine. October, November and December, 1878. January, February and March, 1879.

From Welton and Bonnett, Waterbury, Conn:

Twelfth Report of Water Commissioners of the city of Waterbury. Waterbury, Conn. 1879.

Rules and Regulations made by the Board of Water Commissioners of Waterbury. Waterbury, Conn. 1878.

From John Whitelaw, Cleveland, Ohio:

Twenty-second Annual Report of Board of Trustees of Cleveland Water Works Cleveland. 1878.

From Don J. Whittemore, Milwaukee, Wis.:

General Specifications for a wrought-iron Railway Draw Bridge, to be erected for the Chicago, Milwaukee and St. Paul Railway Co., over a Canal in Milwaukee. Milwaukee. 1878. (6 copies)

From W. W. Wilson, Yonkers. N. Y.

Sixth Annual Report of the Board of Water Commissioners, city of Yonkers. Yonkers, N. Y. 1879. (Copies for distribution.)

From other Sources;

The American Catalogue. Vol. I. Authors and Titles: Part 1. A—Edwards. New York. 1878.

Hevner's New Elevated transmission Line or System of transportation. New York, 1878.

List of serial publications now taken in the principal libraries of Boston and Cambridge. Cambridge, Mass. 1878.

Official Catalogue of the Main Building and Art Gallery. Permanent Exhibition. 1877. Philadelphia. 1877.

ANNOUNCEMENTS.

Members who desire to secure complete sets of the Transactions of the Society are requested to send to the Secretary a list of the papers which are needed to fill their sets. Some of the earlier papers are out of print. If orders are received for a sufficient number to warrant the expense, a reprint will be made.

The following resolution was adopted at the Ninth Annual Convention of the Society, and ordered printed regularly in the Society publications:

Whereas, the metric system of weights and measures is now extensively used abroad; and whereas, it is desirable that the relation of the units of differing systems be made familiar to all, by comparison:

Resolved, That Members be requested, in papers hereafter presented to the Society, to write, in parenthesis, weights or dimensions by the metric system, in connection with those of the system in general use.

The House of the Society is at 104 East Twentieth street, one door east from Fourth avenue, and near southwest corner of Gramercy Park. It is open from nine o'clock A. M. to five o'clock P. M. each business day except Saturday, when it is closed at three o'clock P. M.

The Library and Conversation Rooms will also, for the present, be open every *Thursday evening*, from 7½ to 10 P. M. Members are invited to avail themselves of the opportunities afforded on Thursday evenings both for consultation of books and periodicals and for conversation.

LIST OF MEMBERS.

ADDITIONS.

MEMBERS.

Date of Election.

Bradley, William H....Superintendent Department of Sewers, City Hall, Boston, Mass.....Feb. 5th, 1879

Smith, Hamilton, Jr....Civil and Mining Engineer, San Francisco, Cal..... " "

Date of Election.

SWEET, ELNATHAN, JR...Div. Engineer New York State Canals, Albany, N. Y.....Nov. 6th, 1878

CHANGES AND CORRECTIONS.

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CAMPBELL, JOHN C.....715 Madison avenue, New York.

CHESTER, STEPHEN.....108 Liberty street, New York.

CHITTENDEN, SAMUEL H..Ass't U. S. Engineer, Elk River Shoals, Wheeler, Lawrence Co., Ala.

FROST, B. D.....Littleton, Mass.

GRAHAM, CHARLES K....Surveyor Port of New York, Custom House, New York.

HARRIS, ROBERT L.....Care of David Kimball, Portsmouth, N. H.

JOHNSON, THOMAS H.....Engineer to Contractors Indiana State House, 75 West Market street, Indianapolis, Ind.

MASTEN, C. S.....Chief Engineer Decatur and State Line Railroad, Streator, Ill.

MERRILL, WILLIAM F....Chief Engineer and Superintendent T. P. and W. R. R., Peoria, Ill.

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SMITH, ISAAC W.....Chief Engineer of the Board of State Harbor Commissioners, 10 California street, San Francisco, Cal.

TRUESDELL, CHARLES ....Engineer Water Works, Syracuse, N. Y.

WARFIELD, A. G., JR.....Assistant State Engineer, Sacramento, Cal.

WEEKS, HARVEY R.....Div. Engineer Cin. South. R.R., Chattanooga, Tenn.

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WHINERY, SAMUEL.....Ass't Engineer, Elk River Shoals, Wheeler, Lawrence Co., Ala.

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BACOT, ROBERT C.	"	Oct. 22d, 1878
HOPART, N. P., JR.	"	Jan. 7th, 1879
HOW, JAMES	"	Nov. 5th, 1878
MCGEE, JOHN	"	Nov. 4th, 1878
TUCKER, STEPHEN D.	"	Nov. 9th, 1878

DECEASED.

HATFIELD, ROBERT G.	Member	February, 1879
TASKER, THOMAS T., JR.	Fellow	Aug. 19th, 1877

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